HYGIENE

LEWIS'S PRACTICAL SERIES

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HYGIENE AND PUBLIC HEALTH

Richard Reece

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AND

PUBLIC HEALTH

BY

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PREFACE.

The book of the same title as the present one, of which one of us was the author, having run through five editions in the space of ten years, has been taken as the basis of the present work. The great advance in the science of hygiene during the past decennium has necessitated practically the recasting of the older book, the modification of certain matter therein contained, and the addition of much new matter. It has been the aim of the authors in the present work to give in a condensed, though readable, form the essential principles of the science of hygiene and the more important facts in Public Health Administration. The book is more especially designed for those members of the medical profession who are studying for the various Public Health diplomas, but we trust it may serve as a handy guide to the profession generally upon those topics which are connected with the Public Health aspects of

their work. For the convenience of such of the lay public as may become readers, we have endeavoured as far as possible to convey information by the use of generally understood terms and the avoidance of those which are only of technical application.

The subject of Sanitary Law and Administration is necessarily much condensed, but it is designed to convey a sufficient knowledge of the subject to meet the requirements of the majority of readers, and to enable any reader to obtain an intelligent grasp of the subject. Such details of Public Health work as can alone be performed in a chemical or bacteriological laboratory are not included in the present work, as we are of opinion that this important branch of the subject cannot be satisfactorily dealt with in a small general text-book of Public Health, and several excellent laboratory manuals are now in circulation.

L. C. P.
H. R. K.

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HYGIENE AND PUBLIC HEALTH.

CHAPTER I.

WATER.

WATER is a prime necessity of life. Without it, terrestrial animal and vegetable life must cease to exist. The earliest settlements in all countries were, therefore, made in the neighbourhood of water. Towns and villages sprang up on the banks of streams and rivers, on the shores of lakes, and in the neighbourhood of springs; or water was obtained from the soil around these early settlements by shallow excavations or wells. In modern times, sites for dwellings are not necessarily limited to a small area around a natural source of water. Our engineering knowledge enables us, on the one hand, to obtain water by means of wells and borings from great depths beneath the surface of the earth, and on the other to convey water from great distances by means of conduits to the places where it is required.

This latter method was well known to the ancient Romans, many of whose aqueducts and reservoirs are, after the lapse of many centuries, still standing, and serve to fulfil their original purpose. In Rome the total

supply per head was certainly not less than 300 gallons daily for a population of about 1,000,000 people, the greater portion of this vast supply of water being required for public baths and fountains.

London is an instance of a settlement founded originally on the banks of a river, and spreading subsequently away from the neighbourhood of the river only in those directions where a water-bearing gravel overlaid the impermeable London clay. The bed of gravel being of but slight thickness—10 to 30 feet—water was easily reached by shallow excavations or wells; whilst at some places springs flowed out where the gravel terminated, as at Bagnigge, Holywell, and Clerkenwell. Sixty years ago, parts of London where the clay came to the surface, and which are now densely populated, owing to the introduction of a public water supply, were quite uninhabited.

There is reason to believe that the ancient Egyptians, and the Chinese from a remote antiquity, obtained water from great depths below the surface of the earth by means of artesian wells, the water flowing out at the mouth of the well; but the practice of making deep borings in search of water was not introduced amongst Western nations until comparatively recent times.

Sources of Water—Collection and Storage.

The natural sources of water are the rain and snow which fall on the surface of the earth. When the rain has reached the surface of the ground, it is disposed of in the following ways: a portion (*a*) is evaporated; another portion (*b*) flows off in the direction of the inclination of the surface; whilst a third portion (*c*) sinks into or percolates through the interstices of the soil.

The amount of rain that evaporates depends upon the

temperature of the air. The higher the temperature, the greater the evaporation. If the inclination of the surface is *nil*, or only very slight, and the soil is of some depth and of a porous nature, the larger portion sinks into the soil or *percolates*. If, however, the inclination of the surface is great and the soil is not porous, but more or less impermeable to water, the greater portion of the unevaporated rain flows down the incline. It is this portion which forms or helps to swell the brooks, streams, and rivers, which are the natural drainage channels of the locality. In very porous soils, such as pure sand or coarse gravel, the rain so rapidly sinks into the interstices of the soil that the evaporation even in summer is but slight. In nearly all other soils, however, the amount of rain evaporated greatly exceeds the percolation, even in winter.

The portion that percolates, after a certain deduction that must be made for the moisture absorbed by the roots of vegetables and grasses growing on the surface, and which is subsequently evaporated from their leaves, helps to form and renew the underground sources of water. These are made available to man by natural outlets as springs, or by artificial tappings in their subterranean depths through wells and borings.

Rainfall.

The rain that falls on the roofs of houses can be collected and made available as a means of water supply. To calculate the amount of water supply per head from this source, we must know the amount of roof space per individual (the slope of the roof must not be taken into account, but merely the area of horizontal surface covered by the roof), the average amount of yearly rainfall, and

the average amount of evaporation of the rainfall. As the roofs of houses are, or should be, quite impermeable to water, there is no percolation or sinking in of the fallen rain.

The amount of yearly rainfall varies considerably in different parts of England. In the Eastern Counties the average is less than 25 inches per annum. Throughout the remainder of England the average is from 30 to 40 inches per annum, with very much larger amounts in the mountainous and hilly districts of Devonshire, Wales, Cumberland, and Westmorland (60 to 200 inches per annum). The expression "an inch of rainfall" implies that 1 cubic inch of rain-water has fallen upon each square inch of horizontal surface.

The amount of evaporation from the surfaces of roofs may be taken as averaging throughout the year 20 per cent. of the rainfall. The evaporation is greatest where the rainfall is least, and *vice-versâ*. If the amount of roof space per head in a town is 60 square feet, and the rainfall 30 inches in the year, deducting one-fifth for evaporation, 207,360 cubic inches of rain (= 120 cubic feet or 748 gallons) is the amount available for each person in a year, which is equal to about 2 gallons daily. This is the amount available from the rainfall—30 inches—of an average year. It has been found from a great number of records of rainfall extending over a long series of years in different places, that the rainfall in the driest year is one-third less than the average fall, whilst in the wettest year it is one-third greater than the average. So that in a very dry year, in the example given above, the amount of water available may be only $1\frac{1}{3}$ gallons daily per head, whilst in a very wet year it may be $2\frac{2}{3}$ gallons.

Rain is also sometimes collected from prepared surfaces of ground, which, together with the storage reservoir

or tank, should always be railed off to keep live stock away. The surface of a certain area of land in an exposed situation is rendered impermeable by a covering of slates, asphalte, or cement, and sloped towards an outlet pipe or pipes leading to a tank or reservoir. In estimating the amount of water that can be obtained from such a surface, calculations may be facilitated by remembering that one inch of rain delivers 4·673 gallons on every square yard, or 22,617 gallons (101 tons) on each acre.

Rain, as it leaves the clouds, is water pure and simple, free from all foreign ingredients. In its passage through the air to the earth it may collect various impurities—gaseous and suspended. The rain falling in towns is found to have absorbed sulphurous and sulphuric acids, always present in the air of towns from combustion of coal and coal gas, and to contain numerous sooty particles.

From the observations made at Montsouris, near Paris, by Dr. Miquel, it also appears that the rain washes out of the air countless bacterial and fungoid organisms and their spores. The rain which first falls in a shower, and that which falls after a period of dry weather, contains far larger numbers of bacteria than that which falls later on in a storm, or succeeds the first shower; 200,000 germs per litre is not an unusual quantity under the first set of circumstances. During the warm months of the year, the number of bacteria in the rain are greatly in excess of those found in the rain falling in winter and early spring. The greater number of the organisms in rain are micrococci. All the organisms found in rain exist to a larger extent in the form of spores than in the adult state. Besides bacteria, pollen of grasses and flowers, microscopic plants such as *Protococcus pluvialis*, and spores of fungi are occasionally found in rain, the latter being on rare occasions in sufficient quantity to

cause a localized fall of what is known as "coloured rain."

Rain is thus seen to be a great purifier of air, for it washes out of it gaseous and solid impurities, organic and inorganic. For this reason also the rain which falls in the impure smoke and soot-laden atmosphere of large towns is unfit to drink.

When roofs are used as collecting surfaces for rain water, the first portion of rain which falls and descends from the roof should be rejected, as it is liable to be much polluted with soot, vegetable matter (leaves), and animal matter (excrement of birds, etc.) washed off from the slates or tiles. After the first washing, the remainder of the water may be collected and stored. Roberts's Rain Water Separator effects this purpose by allowing the first portion of water that passes through the apparatus to run to waste through a pipe at its base. After a certain time the apparatus, which is balanced on a pivot, cants over, owing to its centre of gravity being altered as one of its compartments fills with water, and the water escapes through the outlet below into another pipe, which conducts it to a storage cistern. Rain water should always be stored in as pure a condition as possible, otherwise the storage receptacle becomes coated with foul matters, which putrefy and poison the water. The advantage of underground storage is that the water does not get frozen in the winter or unpleasantly hot in the summer. But, on the other hand, the tanks are difficult of access. Underground tanks must be built of sound masonry and lined with hydraulic cement. They should rest upon a bed of concrete and be covered over with arches of masonry ; and if there is a special danger of polluting material gaining access to the tank, they should be surrounded with at least a foot of well-puddled clay.

Rain water is especially useful for cooking and washing on account of its *softness*—that is to say, its freedom from the salts of lime or magnesia in solution. When these salts are dissolved in a water they render it *hard*. Hardness is usually reckoned as equivalent to so many grains of chalk or carbonate of calcium per gallon of water. A water containing more than 10 grains of chalk or its equivalent in other salts (sulphate or chloride of calcium, carbonate of magnesia, etc.) to the gallon is said to be hard. Hardness due to the presence of carbonate of calcium, which is chiefly held in solution in the water by its combination with carbonic acid as a bicarbonate, is said to be *temporary*; for when the water boils, carbonic acid is driven off, and the chalk, no longer able to remain in solution, is precipitated.

It is this deposit of chalk which causes the fur on the bottom and sides of boilers and kettles. When meat or vegetables are cooked by boiling in hard water, a certain amount of the hard material is deposited on their surfaces, which either hinders the proper penetration of the heat into the interior, or prevents solution of the soluble materials when this is desired. The fur lining is also a non-conducting material, and impedes the passage of heat from the fire to the contents of the boiler or kettle, thus causing a waste of fuel. This fur lining is one of the causes of the boiler explosions, from which loss of life not infrequently results. To reduce the possibility of such explosions the following precautions are desirable:—The boilers should be of wrought iron, properly tested; they should be periodically inspected and cleaned; pipes connected with them should not be carried up external walls where they may be affected by frost, and the cisterns should also be in well-protected positions; the safety-valve should be

accessible, easily adjusted, and sensitive to variations of pressure.

Great waste of soap, too, is caused by the use of hard water in washing. In washing it is necessary to produce a lather of the soap with water; but when the water is hard, the lime or magnesia combines with the oleic or stearic acid of the soap (hard soap being chiefly a stearate of sodium, soft soap an oleate of potassium), forming a curdy precipitate; and all the lime or magnesia of the water must be so deposited before a lather can be formed. Consequently a certain amount of soap is wasted. One grain of chalk wastes about 8 grains of soap.

The hardness of rain water is generally less than half a degree; that is to say, there is less than half a grain of chalk or its equivalent salts to the gallon of water; hence its value for domestic purposes. Rain water should never be allowed to run to waste where the water derived from other sources is hard. There is one great disadvantage possessed by rain and other soft waters, namely, their liability to dissolve lead, iron, or zinc if left in contact with these metals. Consequently cisterns of lead, iron, zinc, or galvanized iron should not be used to store soft water; and such water when collected from lead roofs should not be used for drinking.

Upland Surface Waters.

In hilly districts, the water which flows off the hills in the form of rivulets and streamlets can be collected and stored by building an earth and masonry dam or barrier across the outlet of the valley to which the streams converge. By this method of collection in "impounding reservoirs," large artificial lakes are formed, usually at considerable elevations above the towns which they

supply with water, and capable of holding a supply sufficient for several months. A certain amount of "compensation" water (usually estimated at one-third the amount impounded) must be allowed to pass down to any mill-owners on the streams whose waters have been diverted.

Large storage reservoirs for such waters are made by excavation or embankment, and then lining the floor and sides with concrete or well-puddled clay; common mortar must not be used, as the water takes up the lime. Their position should be such that a jet reaching 20 feet above the highest house to be supplied is assured by gravitation alone, otherwise the water has to be pumped to a higher elevation. Means are generally taken for diverting the tributary streams from the storage reservoir by means of a by-wash, when these get foul in times of flood. The size of a storage reservoir for a catchment area will depend upon the numbers of the community requiring the water, and upon the mean rainfall of the district.

Hawksley's formula is of value in estimating the number of days' supply (x) which must be stored when a community is dependent on a rain-water supply. In this formula $x = \frac{1000}{\sqrt{y}}$; where y = the mean rainfall during the three driest consecutive years—which is usually about one-fifth less than the average. In this country from 120 to 300 days' supply have to be stored.

The probable daily yield (in gallons) of a catchment area (x) may be arrived at by Dr. Pole's formula, in which

$$x = 62\,A\left(\frac{4}{5}Rm - E\right).$$

In this formula A = the area of the gathering ground in acres; Rm = the estimated average rainfall of the

three driest consecutive years; and E = the loss of rainfall by evaporation, percolation, and unavoidable waste. The value of E may be as little as 10 inches, and may even exceed 20.

Peaty matter is very frequently present in the upland surface waters of mountainous districts, often imparting a decidedly yellow or brownish hue to the water. It may be removed by filtering the water through beds of fine, sharp sand, as is done at Vartry (Dublin).

Under the heading of Upland Surface Waters may also be considered the waters derived from natural lakes in mountainous districts, of which Glasgow furnishes a good example. Glasgow is supplied with water from Loch Katrine, 34 miles north of the City. This beautifully soft and pure lake-water, which replaced in 1859 the grossly-polluted supply drawn from the Clyde, has been of inestimable advantage to Glasgow, not only by raising the standard of health of its inhabitants, but also by effecting an enormous saving in manufacturing and industrial pursuits, from the fact of there being hardness equivalent to but 1 grain of lime per gallon of the water instead of several. The saving in soap alone is estimated at £36,000 per annum.

Upland surface and lake waters approach more nearly to the composition of rain water in their comparative freedom from mineral matters than waters derived from any other source. Many of the manufacturing towns in Lancashire and Yorkshire are supplied with upland surface waters.

Manchester has lately obtained a new source of supply from Thirlmere, 90 miles from the City. By the construction of a dam, the level of the lake has been much raised, and its storage capacity increased. Liverpool, by immense engineering works, has impounded the waters

of the Vyrnwy, in Wales, creating an artificial reservoir $4\frac{3}{4}$ miles in length, and conveying the water a distance of 68 miles; and Birmingham is now engaged in the task of bringing water from the upper sources of the Wye.

Occasionally the water of lakes and open reservoirs becomes contaminated by the growth and subsequent decay of algæ and other microscopic organisms. In some instances, so abundant is the growth of the organism that the water becomes coloured red or green-blue, according to the nature of the organisms, and is also turbid and evil-smelling. Beyond the unpleasantness arising from the odour and turbidity of the water, and the disturbance of the sand filter-beds when the reservoir water is subjected to filtration, it does not appear that this contamination induces any injurious effect upon the health of the consumers.

The quantity of water that can be collected and stored in an impounding reservoir amongst hills can be calculated with some approach to accuracy if the area of the catchment basin, the average rainfall, and the average amount of percolation, evaporation, and flow of the rainfall off the surface, are known. Records of the rainfall, percolation, etc., extending over a long series of years are necessary for this purpose. The loss from evaporation in open reservoirs may reach to $\frac{1}{6}$ of an inch per day in summer, the average throughout the year varying from $\frac{1}{12}$ to $\frac{1}{16}$ of an inch daily. The area of the catchment basin or gathering ground can be ascertained from a 6-inch ordnance map. It is in many cases a district enclosed by a ridge line, which is continuous except where the water finds exit; or if the ridge line is complete, and the water does not find an exit, a lake or natural reservoir is formed. The main ridge line may

give off branches, and thus produce subsidiary or secondary catchment basins.

In 6-inch ordnance maps, contour lines, which are lines of equal altitude, are drawn at every 25 feet (vertical) of elevation apart. Ridge lines, or watershed lines, along the whole of their course are higher than the ground immediately adjacent on each side, the land sloping from them at both sides. On the ordnance map will also be found the Bench Mark figures, which indicate in feet the height of the particular spot above ordnance datum. If the place noted by any of these figures be visited, there will be found a B. M. or broad arrow marked on some object, such as a milestone, church-wall, rock, etc. The ordnance datum is the standard of height from which measurements commence; it is the mean level of the Mersey at Liverpool.

Streams and Rivers.

Streams near their sources, passing through uncultivated land on hills and moorlands devoid of human habitations, are good sources of water-supply; they form, in fact, those upland surface waters which have already been considered.

Streams and rivers in their course through cultivated valleys, with towns and villages on their banks, furnish water which must always be regarded as *suspicious* from the health point of view, and are in many cases dangerously polluted.

The composition of river water, as regards its mineral ingredients, is most variable. Fed from a variety of sources, by springs and streams in the uplands, by surface drainage, by springs in their beds, and by other streams and rivers throughout the whole of their course, rivers are a combination of spring and surface waters, and

present sometimes chiefly the characteristics of the one and sometimes those of the other. Most river waters are hard waters, containing in solution the salts of lime and magnesia, which in some cases are derived from the springs which feed the river and its tributaries. Thames water, for instance, contains 15 grains to the gallon of lime salts, or their equivalents.

But it is not these inorganic matters which cause river waters to be looked on with suspicion, but rather those pollutions of animal origin to which all rivers, as being the natural drainage channels of the surrounding land, must be subject. The surface and subsoil drainage from manured land under cultivation, trade effluents, the slop waters and the sewage of villages, and sometimes even of towns, and of isolated houses, frequently flow into the river, which they pollute with organic matters, fresh or putrid, of animal origin, amongst which may be included the specific poisons of infectious disease. Towns, as a rule, draw their supply of water from a river above the spot at which the sewage of the town is discharged. But the intake of the next lower town on the banks of that river must necessarily be from a stream already polluted with sewage; and the question arises, Can a river once polluted with sewage, and with all the possibilities of specific disease contamination thereby introduced, ever be a safe source of supply below the source of pollution?

When sewage or other polluting liquids are discharged into rivers, they are more or less diluted with the river water, the amount of dilution depending on the comparative volumes of sewage and river water which are thus mixed together. If the river into which the sewage is discharged consists of clean and hitherto unpolluted water, the atmospheric oxygen dissolved in it will, to a

certain extent, oxidize the organic matters of the sewage, this destruction being very largely effected through the agency of aerobic or oxygen-requiring bacteria. If, too, the dilution of the sewage with clean water is considerable, plant life is not interfered with, but continues to give off oxygen, reoxygenating the water, and enabling the process of purification by oxidation to continue. No doubt, too, as the oxygen dissolved in the water is used up, fresh oxygen is absorbed from the air. Besides water plants, minute animals (infusoria, anguillulidæ or water worms, entomostraca or water fleas, etc.) aid the process of purification by feeding on the organic impurities of sewage. These organisms are found in countless numbers in the polluted reaches of rivers. Fish, too, if the pollution is not sufficiently great to cause much diminution of dissolved oxygen in the water, feed on some of the elements of sewage, and aid in the process of purification ; and if the current is sluggish, or in the deep and quiet pools of a rapid stream, the suspended matters of the sewage will be largely deposited.

The result of all these processes is that, under certain conditions and within certain limits, streams and rivers which have been polluted are capable of undergoing a certain amount of self-purification by natural means. How far this self-purification extends—in other words, its greater or less completeness within a certain distance of flow—is still a matter of doubt. The Rivers Pollution Commissioners (Sixth Report) came to the conclusion, as the result of their experiments, that "the oxidation of the organic matter in sewage proceeds with extreme slowness, even when the sewage is mixed with a large volume of unpolluted water, and that it is impossible to say how far such water must flow before the sewage matter becomes thoroughly oxidized. It will be safe to

infer, however, from the above results, that there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation." On the other hand, several eminent chemists have expressed their belief that a flow of even a few miles is sufficient to free a river of all trace of sewage contamination.

The truth of the matter then appears to be, that under favourable conditions, when the dilution of the sewage with clean water is very considerable, and the oxidation and purification exerted by aquatic animal and vegetable life can have free play, a stream or river, especially if it undergoes agitation and exposure to the air by flowing over rapids or by falling over weirs, is capable of being so far purified that, although it may never quite regain its original purity, it becomes at least very much improved. Practically, however, in this country, a majority of our streams and rivers are not allowed a chance of self-purification. The pollution is almost continuous from their sources to their mouths.

When the river into which sewage is discharged is already much polluted, or if the dilution is not sufficiently great, oxidation and purification are brought to a standstill. The dissolved oxygen is greatly diminished in amount; animal and vegetable aquatic life is injuriously affected or destroyed; decomposition and fermentation of organic matters is started, with the production of foul gases; the bed of the river becomes silted up with decaying matters, which, buoyed up by gases, occasionally rise to the surface and sink again, and a most serious nuisance results. The process is one eventually tending to purification by resolution of complex organic bodies into their simpler elements, but in the meantime the effects of the process are most offensive.

A considerable rise of temperature will produce a like

result on rivers which are having their purifying powers tested to the height of their capacity. Purification goes on so long as the weather is cool, but with a rise in temperature, bacterial growth is stimulated, and decomposition sets in, replacing the oxidizing processes.

Sewage in potable waters—waters intended for drinking—is chiefly dangerous from the fact of its containing, or being liable to contain, the specific poisons of disease. Cholera and enteric fever, diarrhœa and dysentery, we know to be sometimes spread by means of infected and polluted water.

A considerable mass of evidence was submitted to the Royal Commission on Metropolitan Water Supply (1893), as to the fate of disease poisons subsequent to their introduction into river water. This evidence was founded almost entirely on laboratory experiments on the behaviour in water of the supposed bacilli of typhoid fever and cholera. The statements of the bacteriological witnesses before the Commission, therefore, represent knowledge obtained under artificial conditions of disease organisms cultivated under similar conditions, and are, consequently, only inferentially applicable to similar microbes in a state of nature, and subjected to a natural, as opposed to an artificial, environment.

With this reservation, the general results of the bacteriological evidence may be summed up as follows: The bacilli of typhoid and cholera tend to lose their vitality and ultimately to disappear, when placed in water. In water which is sterile, or devoid of other organisms, these bacilli may retain some kind of vitality for several weeks or months. But in water containing actively growing aquatic or saprophytic bacteria, such as ordinary river water, the destruction of the pathogenic organism is effected much more rapidly. This statement helps to

throw light on certain outbreaks of enteric fever due to specific contamination of deep well-water. Pure deep well-waters contain relatively few bacteria, consequently the typhoid bacillus when introduced into such a water (as occurred in the Caterham outbreak) may retain its vitality and virulence sufficiently long to render enormous volumes of water infective. It appears, also, that under such conditions, deep down underground, with an absence of light, the typhoid bacillus for a space of two or three days increases in numbers to a vast extent, thus enabling a relatively small amount of polluting ingredient to contaminate large volumes of water.

The process of sedimentation which occurs in the deep and sluggish reaches of a river tends to the elimination of bacteria, the suspended matters in their subsidence carrying down with them, entangled in their substance, numberless bacteria. The effects of aeration and of flow are less apparent *quâ* bacterial destruction; whilst as regards the undoubted powerful germicidal action of bright sunlight, in the case of a river like the Thames, with an average depth of over six feet, it is doubtful what effect the water has in cutting off the actinic light, and, therefore, what is the precise germicidal action of sunlight or daylight at different depths from the surface, and under different conditions of clearness or turbidity of the water.

The process of storage and purification pursued by the London (Thames) Water Companies, on the efficiency of which the health and freedom from disease of so large a population depends, is as follows.

The water taken from the river at Hampton and Molesey is passed into a storage reservoir of masonry, capable of holding several days' supply. It is important that the capacity of this reservoir should be sufficiently

great both to obviate the necessity of drawing water from the river when it is in flood, and therefore very turbid, and to allow time for the clarification of the water by the deposition of all its suspended matters. The five companies supplying Thames water to London have storage reservoirs of an aggregate capacity of 516 million gallons, and the average daily supply from these five companies is 107 million gallons. From the storage reservoirs the water passes on to the surface of the filter-beds, which consist of layers of fine sand (average thickness 3 feet) lying upon layers of gravel, fine above, but coarse below, and of a total depth varying from 3 to 8 feet. In the coarse gravel or rough stones are the open mouths of the outlet pipes, which convey the filtered water from the filter-beds to a central filtered-water well, from whence it is pumped through iron mains to the Metropolis, or to a high-level reservoir near London. Vents run up from the deeper layers of the filters to above the water level to permit of the escape of displaced air when the bed is being filled with water. The large storage reservoirs in or near towns should be covered; and not unfrequently these are made to feed supplementary reservoirs, especially where the demand in one part of the district greatly exceeds the average for the district generally.

The depth of water on the filter-beds is never more than 2 feet, the average rate of filtration per square foot of filter-bed being $1\frac{3}{4}$ gallons per hour. The upper layers of fine sand must be occasionally renewed, as they become choked with sediment. They are usually removed, and washed with water jetted from a hose under high pressure, before being used again in the filter-beds.

Sand acts almost entirely as a mechanical filter, but a small amount of purification by oxidation takes place.

This purification results mainly from the condensation of oxygen, which takes place upon the upper surface of the sand. Dr. Percy Frankland has shown that the micro-organisms (harmless) present in unfiltered Thames water at Hampton are reduced in number on the average 97·7 per cent. by the storage and filtration which the water undergoes at the hands of the water companies, but that this reduction is largest in the case of those companies which have the largest storage capacity for unfiltered water, the greatest thickness of fine sand in the filter-beds, the slowest rate of filtration, and the most frequent renewal of the filter-beds—all these being factors of much influence on the chemical, as well as on the biological, characteristics of the water.

All the witnesses before the Royal Commission on the Metropolitan Water Supply (1893) were agreed that the efficiency of the sand filter-beds in intercepting bacteria is due to the formation of a superficial gelatinous deposit or membrane on the top of the sand. The bacteria become attached to and entangled in the colloidal mass, and are, consequently, prevented from passing down into the deeper beds of sand and gravel. This filtration has been likened to the dialysis through a fine jelly, which is capable of intercepting the very smallest bacteria, if there is no rupture or loss of continuity in the material. This gelatinous film which forms on the top layer of sand consists very largely of intercepted organic matter and bacteria. It appears to be sufficiently well formed to be effective in intercepting bacteria within two or three days after the filter-bed has been in use, subsequent to renewal of the top layer of sand. It follows, therefore, that the filter-bed does not attain its normal efficiency in the interception of bacteria until it has been in use at least two days after the

periodical renewal. On the other hand, there is no evidence of the efficiency of the sand filter-beds, *quâ* bacterial interception, being reduced by prolonged use, even for so extended a period as sixty-eight days. It would seem that the organisms tend to grow down deeper and deeper into the beds, and might possibly in time grow quite through the interstices of the filter, and so reappear in the filtered water. But owing to the thickness of sand this process must occupy a very long time. The reason why the top layers of sand should be skimmed and renewed periodically is to prevent other filter-beds being overtaxed, because the filtration becomes slow in the old beds, owing to the thickness of the gelatinous coating, and consequent clogging of the top layers. If certain filter-beds are working too slowly, others have to be pressed, possibly resulting in inefficient filtration, in order to make up the volume of filtered water necessary for the daily supply.

The results of the Massachusetts experiments on the purification of water by filtration may be briefly summarized as follows:

(*a*) By reducing the rapidity of filtration, and employing the finer sands, increased efficiency is obtained.

(*b*) With moderate rapidity of filtration (2,000,000 gallons per acre per diem) 1 foot of sand appears to be as effective as 5.

(*c*) The scraping off of the upper layer of clogged sand enables more organisms to pass through the filter; and it is not, as a rule, until three days after scraping that the filters regain their highest efficiency.

(*d*) Fifty-five per cent. of the organisms removed were found in the upper $\frac{1}{4}$-inch of sand, and 80 per cent. in the upper inch.

(*e*) Much less water at 32° F. passes through a filter

than when the water is at 70° F., owing to the increased viscosity of the colder water.

(*f*) Shallow filters require more frequent scraping than the deeper ones, due to the greater head available in the deeper filters.

(*g*) Filters used continuously require less frequent scraping than when used intermittently.

The connection between the cholera outbreak in Hamburg in 1892 and its water-supply, and the value of sand filtration, are clearly demonstrated by the following facts:—Hamburg, Altona, and Wandsbeck are three towns which are contiguous to each other, and really form a single community, not differing from each other except in so far that each has a separate and different kind of water-supply. Wandsbeck obtained filtered water from a lake which is hardly at all exposed to contamination with fæcal matter; Hamburg obtained its water unfiltered from the tidal Elbe above the town; whilst Altona drew its water from the Elbe, but below Hamburg, after the river had received the sewage of 800,000 people. The water so taken, however, was subjected to careful sand filtration before being supplied to the people of Altona. Whereas Hamburg in 1892 was severely visited by cholera, nearly 17,000 attacks and 8,600 deaths occurring between August 16, when the disease was first introduced, and the middle of November, when it had subsided (annual death-rate from cholera in 1892 = 13·4 per 1,000 of the estimated population), Wandsbeck and Altona were nearly free from the disease. About 500 cases of cholera occurred in Altona, but at least 400 of these were infected in Hamburg. The water supplied to Hamburg was taken from the Elbe above the sewage outfalls into the river, but was nevertheless contaminated at times by the tidal action carrying sewage

back above the outfalls. This water, supplied in an unfiltered condition to the population, was the cause of the cholera epidemic. Careful sand filtration of the Elbe water, in a much more grossly sewage-polluted condition, saved Altona from the disastrous epidemic which raged in Hamburg.

Professor Koch lays stress upon the following three points as to the efficacy of sand filtration: (1) That a proper thin layer of mud or slime should be formed on the top of the filter-bed; that it should not be disturbed during the process of filtration, and that, when the deposit becomes too thick and impermeable, it should be removed; (2) that the thickness of sand should never be less than 30 cm. (11·8 inches); (3) that the downward movement of the water through the sand layer must not exceed 100 mm. (3·94 inches) in the hour, or 200,000 gallons per acre per hour. He recommends that, after a filter has been scraped, the slimy deposit should first be allowed to form before the water is conducted to the filtered-water well or reservoir; that each separate filter should be bacteriologically investigated daily, and water containing more than 100 germs, capable of development, in a cubic centimetre, should not be allowed to reach the pure-water reservoir. The majority of the bacteria in adequately filtered water are attributable to post-filtration sources, the filter-beds below the slime layer, the channels, collecting drains, culverts, and wells being of course not sterile. The slightest disturbance, however, in the process of filtration, as, for instance, the quickening of the pace of filtration to over 100 mm. per hour, or the disturbance of the mud surface covering, as in periods of frost or immediately after a filter is cleaned, tends to create an immediate increase of germs in the filtered water.

The conclusion that we may come to, then, in the case of the London water-supply from the Thames, is that, as long as it is efficiently filtered, and not taken from the river when in flood, it is fairly pure and reasonably wholesome; but that the Thames is not really a safe source of supply, for should the filtering arrangements break down at a period of epidemic prevalence in the upper reaches of the river, disease would in all probability arise amongst the consumers of the water in London. The same may be said of any other polluted river used as a source of drinking water; and all attempts to purify by filtration organically polluted water ought to be deprecated, whether it be on a public or domestic scale.

Mr. Murphy shows that in each of the four years 1890-1-2-3 there was a decrease in the notified cases of enteric fever in London in the 49th, 50th, and 51st weeks of those years; but in 1894 there was an increase in the notified cases of this disease in comparison with the preceding weeks, and this increase followed upon very remarkable floods in the Thames and Lea valleys in the 46th and 47th weeks of the year, and the delivery in London of inefficiently filtered water containing an abnormal amount of organic matter. The cases of enteric fever were scattered all over the Metropolis, and were not localized to any particular district, there being in fact no localized outbreak to account for the increased number of cases in the 49th, 50th, and 51st weeks of the year.

The yield of a small stream, or water-course, may be approximately ascertained by observing the average width and depth of the stream over a portion of the channel where it is pretty uniform. The yield is found by multiplying the area thus obtained by four-fifths of

the surface velocity in this portion of the channel. Current metres may also be employed; or, if the whole stream is dammed up and made to pass through a trough of known area and length, through a sluice of known size, or over a weir in which a rectangular notch is cut, the discharge of water can be estimated. When water is taken from the head of a stream for municipal purposes, a "compensation reservoir" is often provided to impound storm waters, which can be led into the river for trade purposes to augment the dry-weather flow.

Springs.

In its passage through the soil, the portion of the rain that percolates absorbs carbonic acid from the ground air, which is very much richer in this gas than ordinary atmospheric air. This water holding carbonic acid gas in solution is capable of dissolving some of the mineral constituents of the rocks over which it passes.

The most important minerals found in underground waters are:—calcium carbonate from chalk, oolite, limestone, and sandstone; calcium sulphate from the same strata and from selenite; magnesium carbonate and sulphate from magnesian limestones; iron from the greensands and from the new red sandstone; and salts of sodium or potassium from greensand, sandstone rocks, and other strata. The advantages of underground water supplies over surface supplies are that large reservoirs are not required, less land is wanted, filtration is unnecessary, and there is less liability to pollution. In some springs, derived from underground waters at great depths below the surface of the earth, the mineral constituents of the water are so excessive in amount as

to render it quite unfit for drinking, but valuable for medicinal purposes. The temperature of such springs is also often high. There can be little doubt that the water giving rise to these springs is, in many cases, forced out of the earth by the pressure of confined gases. But the origin of most of the springs which afford a pure and wholesome water for ordinary use may be explained in a different manner.

The rain which percolates into the porous strata (sand, gravel, fissured chalk, sandstone, etc.), at the surface of the earth, sinks through these strata by the force of gravity until it reaches—as it usually does at a greater or less depth — an impermeable stratum. Prestwich says that on chalk hills it takes four to six months for the rainfall to reach the water-level, if this is at a depth of 200 to 300 feet. This underground water does not always stand at the same level. It is constantly rising and sinking, and in most years these variations of level are fairly regular, both as to amount and as to the season of the year at which they occur. The highest level is usually reached in February or March, whilst the lowest occurs in October or November. The cause of these variations must be looked for in the circumstances attending the rainfall.

In districts having an average rainfall (25 to 30 inches per annum), the amounts of rain that fall in summer and in winter are very nearly equal. But in the summer months (April to September) the amount of rain that percolates is generally very small; it is only one-seventh of the summer rainfall in chalky soils. Nearly all the rain that falls in an average summer is evaporated from the surface of the soil or from the leaves of plants. The consequence is that the underground water is not replenished from the surface, and its level sinks. In the winter months

(October to March) considerably more than half the rainfall percolates in most chalky soils, the remainder being lost by evaporation. The underground water begins to rise usually in November, if percolation has commenced in October, and continues to rise until it attains its maximum in March.

Occasionally it happens, as in 1879, when the summer was very wet, that the underground water rises during the summer months. But such years are exceptional.

There is always a certain amount of percolation in the summer months, and this varies within rather wide limits. In some years it is *nil*, in other years it is—as in 1879—as great as the evaporation (over 12 inches). The reason of this appears to be, that a chalk surface is able to evaporate about 12 inches of rain in the six summer months. If the summer rainfall is much less than 12 inches, there is no percolation at all; but if the rainfall exceeds 12 inches, the difference percolates, and helps to replenish the underground waters. In the chalk, as we have seen, about 37 per cent. of the entire rainfall percolates; in the new red sandstone about 25 per cent.; in the magnesian limestone 20 per cent.; whilst in the loose sands and gravels about 90 per cent. of the rainfall is said to percolate.

The underground water is not only constantly changing its level, but it is also always moving slowly towards its natural outlet. The water tends to find its own level according to the laws of gravitation; not rapidly but slowly, owing to the friction and capillarity which obstruct its passage through the interstices of the rocks or soil. The outlet may be into the sea, or into a river, or by springs on a hillside, at a much lower level.

It has been found by observation on deep wells that the underground water has a curved surface from its

highest level to its outlet. The curve rises steeply from the outlet, but gradually becomes more nearly horizontal as the distance from the outlet increases (Fig. 1). The variations in level between high and low underground water are small near the outlet, whilst they gradually

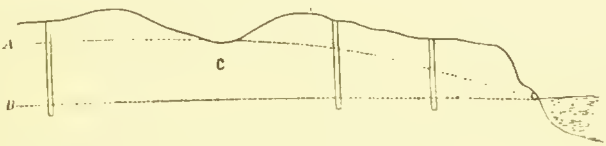


FIG. 1.—UNDERGROUND WATER CURVES.
A, High level; *B*, low level; *C*, intermittent spring.

increase as the distance from the outlet increases. The higher the level of the underground water, the greater is the fall from its highest point to the outlet, and, consequently, the larger the volume of water discharged at the outlet.

Springs are formed by the "cropping out" on the surface of the earth of the impermeable stratum which holds the underground water up, *i.e.*, prevents it from sinking further into the earth. They are natural outlets of underground water, and are usually divided into "main" and "land" springs.

Land springs are the outlets of limited collections of underground water, formed in superficial beds of sand or gravel overlying an impermeable stratum. They are often intermittent, ceasing altogether to flow during the summer, when the underground water is exhausted, and beginning again in the autumn, very soon after percolation commences. Intermittent springs are also formed where a valley cuts across the highest levels of a large volume of underground water, so that the spring flows only for a short period of every year—usually in February or March

—when the highest water-line of the underground water is tapped by the depression of the valley (Fig. 1).

Main springs are the deep-seated springs issuing from regular geological formations, such as chalk, oolite, sandstone. They are usually perennial, flowing all the year round, but exhibit well-marked seasonal variations, their volume increasing in winter, when the underground water level stands highest, and the fall to the outlet is greatest.

Springs afford good sources of water supply for small communities, such as villages. Main springs are better than land springs, both because, as before stated, they yield water throughout the entire year, and because they are less liable to accidental pollutions, the great thickness of strata through which the water percolates from the surface effectually dealing with any organic impurities it may contain. Such spring water is usually clear and sparkling, well aerated, and of nearly constant temperature throughout the year. It generally contains more or less of the salts producing hardness, and is, therefore, though palatable and wholesome for drinking, less well suited for washing, cooking, and manufacturing purposes, than the soft waters.

To guard against pollution, the surface of the soil around the point of delivery of the spring should be walled in, and the water conducted to the surface by a short pipe. In some cases it may be necessary to collect the water issuing from a spring, and to store it in a reservoir before distribution to the houses of the consumers.

The yield of a spring may be estimated by observing how long it takes to fill a vessel of known capacity. It is well to know the average flow throughout the year.

In chalk and sandstone districts springs are comparatively rare, unless it be at points much below the level of

the surrounding country, as these permeable rocks themselves form vast reservoirs. In the oolite, owing to the frequent alternation of porous and retentive strata, springs are common. In limestone regions main springs are often fed by subterranean reservoirs caused by the solution of the limestone by water charged with CO_2. The most constant and abundant springs in this country are generally in the chalk, oolite, new red sandstone, the millstone grits, and mountain limestones; and the most invariably good water is obtained from the lower chalk immediately above the greensand.

Springs may be made to supply water to houses situated above the level of their delivery, if the flow is sufficient to work a ram, turbine, or other similar form of pumping engine, so that the water can be pumped up to the cistern or reservoir. Sometimes the spring water issuing from a great depth is warm or even hot. This is due to the fact that the temperature of the earth increases with its depth, and the water temperature rises about 1° F. for every 50 to 60 feet of depth, on an average.

Wells.

It is usually said that there are three kinds of wells, *shallow*, *deep*, and *artesian;* but this last is merely a variety of a deep well. The source of the water in wells is the same as that of springs, and the composition of the water will be very much the same as that of the spring water derived from similar strata.

Shallow wells are those which are sunk into superficial porous beds of sand or gravel overlying an impermeable stratum of clay or other dense rock. They tap the underground water held up by the impermeable stratum and yield a water identical in composition with that flowing from the land springs in the neighbourhood.

The depth of the well must, of course, vary with the vertical distance of the impermeable stratum from the surface of the earth; as a rule, this distance is not great, and, in fact, it is often said that shallow wells are those which are less than 50 feet deep; but it is better to keep to the definition here given.

The rural population of this country derives its water almost exclusively from shallow wells. Formerly shallow wells were also the usual sources of supply in towns; but these, in nearly all instances, have now been abolished in favour of a public supply from unpolluted sources. The Rivers Pollution Commissioners (Sixth Report) stated that in their experience shallow wells were almost always horribly polluted by sewage and by animal matters of the most disgusting origin.

The above passage indicates briefly the conditions under which shallow well-waters are often drunk; but it will be advisable to consider the sources of pollution of such well-water somewhat more in detail.

Where the level of the underground water is but a few feet from the surface, it is obvious that the surface water, which may contain impurities, has but little chance of being purified in its passage through the soil to the well. But the grosser pollutions that shallow well-waters suffer from, come, not from this source, but from leaking drains and cesspools in the vicinity.

Cesspools are but rarely made watertight, as they would then require to be frequently emptied. When sunk in a porous soil and merely lined with bricks without mortar or cement, the liquids soak away, and the solids—small in volume—so gradually accumulate that the cesspool can be closed over, and need not be opened for years. The liquid sewage percolates through the soil and joins the underground water below. As the

underground water is—as before explained—slowly but steadily moving along in the direction of its natural outlet, the position of the well in regard to the cesspool is all-important. Should the well be above the cesspool, the underground water flowing from the well to the cesspool, the risk of pollution is greatly diminished, so long as but little water is drawn from the well. If the well is below the cesspool and in the line of flow of the underground water, it must infallibly be polluted with the cesspool soakage. The direction of flow of the underground water can usually be determined from the contour of the surrounding country; and this evidence can be confirmed by observations on the height of the underground water at different places, as determined by the height of the water above ordnance datum in different wells; for the level of the underground water falls as it approaches its outlet in springs, lakes, streams, or rivers, giving rise to a curve which has been already considered (see p. 27).

When, however, the amount of water abstracted is sufficiently great to cause a considerable depression of the water in the well, the conditions are altered, for the well then drains an area all around it in the form of a circle; that is to say, the water in the well is renewed not only from above—as regards the flow of underground water—but from below; and in such a case it would not matter what position the well had to the cesspool, if the cesspool was included within the area drained by the well, for pollution must inevitably occur. The distance within which a well draws water to itself, when its own water-level has been depressed by pumping, depends on the amount of the depression and on the nature of the soil.

The surface of the underground water in the area of

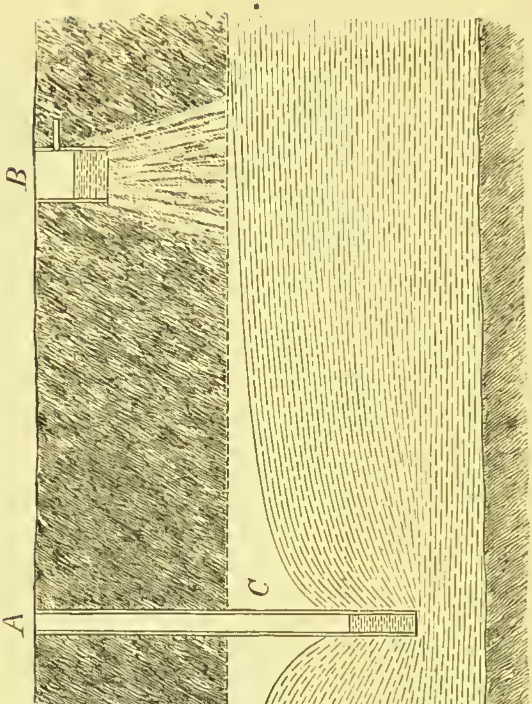


Fig. 2.—Depression of Water in Shallow Well by Pumping.
A, Well; *B*, cesspool; *C*, underground water curve. (After Field and Peggs.)

the circle drained by a well depressed by pumping has the form of a curve, analogous to the natural curve of the underground water, with steep, vertical gradient near

the well, but rapidly becoming more nearly horizontal as the distance from the well increases (Fig. 2).

We have thus seen that the conditions which determine the freedom or otherwise of a shallow well from cesspool or sewage pollution are: (1) Its position as to cesspools or other sources of pollution, with regard to the flow of underground water; (2) the amount of depression of water level in the well which may be produced at any time by pumping; (3) the nature of the soil in which the well is sunk, as regards porosity and the easy passage of water. It is quite possible, if these conditions are attended to, to sink a well that shall be uncontaminable in or near a village, in which the shallow wells are generally polluted with cesspool soakage.

The well must be sunk in such a position as regards possible sources of pollution that the underground water flows from the well to the sources of pollution. The distance of the well from such possible polluting sources should be from 100 to 160 times the depression of the water in the well that is ever likely to be produced by pumping, this distance varying with the nature of the soil. The mouth of the well should be closed over, and the water raised by an iron pump; draw wells, where the water is raised by a windlass, chain, and bucket through an open mouth, are liable to accidental contamination from refuse being thrown in, or animals falling in. To prevent contamination from impure surface washings, the mouth of the well should be protected by a coping, and the drainage water from the pump conducted away to a safe distance.

If the porous stratum in which the well is sunk is of considerable thickness, the underground water being 30 feet or more from the surface, the sides of the well for at least 20 feet should be imperviously steined with

brickwork set in and lined with hydraulic cement; or cast or wrought iron cylinders may be employed for lining the upper portion. If this is done, water percolating from the surface must pass through at least 20 feet of soil before entering the well. In its passage through the soil, the organic impurities in the water will be, to a certain extent, removed. The less the fluctuation in level of the subsoil water, the more likely is the supply to be permanent, and the less the liability to contamination.

It is a curious circumstance in regard to the grossly polluted waters of many shallow wells, that they are, as a rule, clear, sparkling, and very palatable. The organic filth from cesspools and drains, in its passage through even a few feet of porous soil, is filtered and deprived of suspended matters, but without losing its dangerous properties. The shallow well into which the filth percolates is found to furnish a water loaded with ammonia and chlorides—evidences of sewage (urine) contamination—with organic matter in solution, and with nitrates and nitrites, the oxidized residues of organic matters; but yet, from its containing abundance of carbonic acid gas, the water is sparkling and palatable. If such a water, however is put in a bottle, and kept in a warm place, it very soon becomes turbid, then putrid, and is found to swarm with bacterial life. Such wells too, after a heavy rainfall, are very liable to furnish a turbid and foul-smelling water which nobody would think of drinking. The heavy rain washes foul substances in the soil, derived by soakage from manure-heaps, middens, privies, leaky drains, or cesspools, straight into the well, no time being allowed for that filtering and partial purification which does so much to give the well water at ordinary times its pure and deceptive appearance.

Polluted shallow well waters are usually hard, and therefore unsuited for domestic purposes. The hardness is largely due to the polluting liquids which find their way into the well, but little being caused by the mineral salts present in the strata through which the well is sunk. Another source of pollution of shallow wells is the vicinity of graveyards, especially when the subsoil water is liable to rise up to the level of the coffins. What has been already said as to cesspool pollution is quite as applicable to the dangerous pollution arising from this source, especially as regards the flow of underground water, whether it be from the well to the graveyard, or from the graveyard to the well.

Tube wells are contrivances for obtaining water from superficial porous strata by means of borings. They were largely used during the Abyssinian campaign, where the occupation of any piece of ground was necessarily temporary, the tube being quickly sunk and as quickly withdrawn. An iron tube with a steel nozzle and perforations at its lower end for the passage of water is driven into the ground by a driving weight or 'monkey'; before it has altogether disappeared into the ground another length of tube is screwed on, and this is then driven into the soil. Successive lengths of tube are attached until a depth of 20 to 28 feet is reached, when a hand-pump is screwed on the top, and the water pumped out. Difficulty is often experienced from sand blocking the lower part of the tube and the perforations. The sand must be dislodged by a clearing tool, or pumped out until a space free from sand is formed around the nozzle, and the water issues clear and bright. These tube wells are most suitable where the distance of the water from the surface of the ground is not more than a few feet, and it is sometimes

advantageous to drive one from the bottom of an ordinary well to increase its yield.

Deep wells are those which are sunk to considerable depths in search of water through regular geological strata such as chalk, oolite, and sandstone. Those also are known as deep wells which pass through a superficial porous bed and an underlying impermeable stratum to reach water-bearing strata at greater depths, though often at no great distance from the surface. In sinking a deep well, as soon as the water-bearing strata are reached the water often rises rapidly, and may even overflow at the surface.

If the sides of a deep well of this nature are properly steined with brickwork set in cement as far down as the impermeable stratum, surface waters and underground water resting on this stratum are entirely excluded, and the well is freed from those sources of pollution which so often contaminate shallow-well waters. Steining should also be applied to deep wells sunk through porous strata for the whole of the depth of such strata; in this way surface pollutions are compelled to pass through considerable thicknesses of soil before reaching the well. Where the well is deep or where hard rock has to be pierced, it must be either bored or excavated. In hard chalk, new red sandstone, oolites, and limestones, the wells require no lining, but in clays, marls, and in all free and broken strata they should be steined.

The water which supplies deep wells has usually travelled a long distance since it fell as rain on the surface of the earth. The outcrop of the water-bearing strata on the surface may be many miles from the spot at which the well is sunk, as is the case with the deep wells in the chalk sunk through the London basin.

The London basin is interesting as an example of

a geological formation with water-bearing strata in different rocks at varying depths from the earth's surface (Fig. 3). Most superficially are the subterranean waters in the beds of gravel or alluvium of but slight thickness (10 to 30 feet) upheld by the London clay. These waters supplied the shallow wells which formerly formed so large a part of the water supply of London. After boring through the London clay (100 to 400 feet in the neighbourhood of London) water is again reached —or was before these strata were exhausted—in the Lower London Tertiaries, beds of sand, gravel, or clay of variable thickness (20 to 100 feet) with limited outcrops beyond the edge of the London clay, and more or less surrounding it as they rise from the margin of the basin. The places where these beds are best exposed, and from which they take their names, are Blackheath and Oldhaven, Woolwich and Reading, and the Isle of Thanet. Having such a limited exposure to rainfall, the water which accumulated in the deep strata of these beds under the London clay was soon exhausted, when numerous wells were sunk into them.

Beneath the Lower London Tertiaries comes the chalk, with its outcrop in the chalk hills and downs, north, south, and west of the Thames basin, and many miles from its centre. The outcrop forms a very extensive catchment area for rain, which, percolating through the joints and fissures of the chalk, gives rise to vast reservoirs of subterranean water in the underground extension of this rock beneath the tertiary beds of the London basin. As the London basin is hollowed into the form of a shallow trough, the sides of the trough being the outcrop of the chalk in hills and downs, it follows that the water in the chalk is also trough-shaped, and that when wells or borings are sunk

into it near the centre of the London basin, the water tends to rise in the boring, and may even overflow at the surface, forming true Artesian wells. Such wells exist in some of the low grounds of the valleys of the Thames, Wandle, and Lee; but as a rule, in the chalk borings in the neighbourhood of London, although the water rises, it does not reach the surface. In consequence of the number of borings drawing water from the chalk near London, the water level has been lowered; and borings have now to be made deeper than formerly. Owing to the joints and fissures in the chalk allowing a free passage for water, the distance which a well or boring drains, when its water level is depressed by pumping, is very great; and thus borings at considerable distances from one another are mutually affected by continued pumping in any one of them. If a boring in the chalk should not happen

Fig. 3.—Diagrammatic Section through London Basin.

A, Surface gravel, brick-earth, or alluvium; *B*, London clay; *C*, Lower London Tertiaries—sands, gravels, and thin beds of clay; *D*, Chalk, with fissures; *E*, Upper greensand; *F*, Gault; G, Lower greensand.

to open up any fissures or cracks, it may supply but a limited quantity of water, or none at all.

A very large volume of water from the chalk enters the Thames by springs in its bed in the neighbourhood of Windsor. The chalk hills surrounding the western portion of the London basin dip towards the Thames in every direction, but the water percolating through the chalk is blocked by a *fault* (running nearly due north and south a few miles west of London) from escaping into the sea or Thames estuary. The effect of the fault is that the strata are pushed up so as to overlap, and the fissures consequently are closed, thus preventing the water from escaping eastwards. As a matter of fact, water spouts up to the surface from borings in the chalk westward of the great fault or fissure, showing that here the chalk is saturated with water under pressure, whilst eastward of the fault the water in the chalk stands from 30 to 90 feet below ordnance datum. A large portion, then, of the water in the chalk west of the fault is discharged into the Thames above Windsor, because a mile or two below Windsor—from Datchet eastward—the chalk is overlaid by the London clay, through which the water cannot escape to the surface except by means of deep wells or bore holes. The chalk at Windsor is, therefore, the lowest level at which water can escape from the chalk gathering-grounds. The volume so entering the Thames has been estimated at some 300,000,000 gallons daily. It has been proposed to tap the water in the chalk in this neighbourhood, above the springs in the bed of the river, by constructing long tunnels in connection with large receiving wells, and conducting the water so intercepted to reservoirs near London.

Beneath the chalk is the upper greensand in thin

beds (10 to 30 feet) with a very limited outcrop around the edge of the chalk; and beneath this again is the gault, a bluish clay with an average thickness of 130 to 200 feet. Under the gault lies the lower greensand in very thin beds, often completely thinned out, and therefore absent. Although the greensands are rocks permeable to water, neither the upper nor lower beds have yielded water in any quantity to deep borings in the neighbourhood of London. Their outcrop is very limited, with but a small exposure of catchment area for rain; and these formations appear also to thin out considerably in their underground extensions towards the centre of the basin. Near their outcrops in many places the greensands furnish abundant supplies of water.

Several borings made in or near London have passed through all the strata above mentioned into the primary rocks beneath. Thus, a boring at Meux and Co.'s brewery in Tottenham Court Road passes through *made ground* 22 feet, *London clay* 64 feet, *Lower London Tertiaries* 72 feet, *chalk* 655 feet, *upper greensand* 28 feet, *gault* 160 feet, *lower greensand* (?), *Jurassic* 64 feet, *Devonian* (*purple shales*) 80 feet; total depth, 1,146 feet. In making these borings it is usual to excavate a wide well-hole for some depth, from the bottom of which a bore tube of small diameter is sunk. The water should rise through the bore tube in sufficient volume to form a reservoir in the lower part of the well-hole, from which it can be pumped to the surface from considerable depths. Boring tools of large diameter have been recently introduced, and these are found less costly, whilst the borings are more easily made. At some new works in the chalk at Southampton, the bore tubes are 6 feet in diameter. It has been in many cases found that the

driving of headings and adits horizontally below the water-level, is more effective in increasing the yield of wells than deepening them, as the area of collection of water is thereby increased, and there is a greater likelihood of striking the fissures from which the largest volumes of water are obtained.

Artesian wells, so called from the province of Artois in France, where they have long been in use, are formed when a boring taps a subterranean reservoir confined in a permeable stratum by impermeable strata above and below, the permeable stratum having its outcrops on the surface at considerably higher levels than the surface of the ground where the boring is sunk. The subterranean reservoir is consequently basin-shaped; and the water, when tapped at the lower part of the basin, strives to regain its level by flowing up the boring and spouting out at its mouth. The waters which feed these wells often come from a great distance, the outcrops of the permeable strata on each side of the basins, which are the catchment areas for the rain, being sometimes 60 or 70 miles from the well in a straight line. The best Artesian wells are found in the chalk.

The water supplied by deep wells is generally remarkably free from organic impurities, even when sunk in the midst of large cities. Nitrogen, as nitrates and nitrites, is usually present in deep-well waters; the other mineral constituents of the well-water depend chiefly on the strata through which the water has percolated, and on the solubility of the component elements of these strata by water charged with carbonic acid.

The yield of water from a well can be only ascertained by pumping down to a certain level, and observing the length of time required for the water to regain its original level. In this country the largest supplies of

deep-well water are obtained from the chalk, the oolite, and the new red sandstone. An atmospheric or common pump cannot be depended on to raise water more than 27 to 28 feet. Centrifugal pumps are made to raise water over 100 feet; by the revolution of blades working in a case the water is drawn up in a continuous stream and forced into a rising main. Powerful force-pumps are employed in raising the water from great depths.

The motive powers for driving pumps are: (1) the wind; (2) water power, as by the hydraulic ram, water-wheels or turbines, and (3) fuel engines to produce steam when neither wind nor water power is available.

Composition of Water from Various Sources.

The nature and amount of the organic pollution to which water from various sources is liable is such a variable quantity, that it is useless and misleading to attempt any classification under this head; for it is local circumstances that will determine whether a shallow-well water is polluted or a deep-well water is pure. Generally speaking, however, the purest waters are derived from deep springs and wells and upland surfaces, while the waters from the subsoil, from cultivated surfaces, and from rivers are especially liable to be organically polluted. But the character of the soil and subsoil from which the water is collected influences its composition to an extent which, though variable, may be approximately defined.

1. *Surface Waters.*—Those waters collected from the hard surfaces of the practically impervious rocks which support little animal or vegetable life are very pure. They commonly contain less than 10 parts of total solids, 5 of total hardness, 1 of chlorine, and 0·1 of nitrogen as

nitrates, in 100,000 parts of water. The mineral solids consist mainly of sodium carbonate and chloride, and a trace of lime or magnesia. The variable amount of organic matter, which is often exclusively of vegetable origin (peat), yields practically no free ammonia; but the organic ammonia figure and that of the oxygen absorbed by organic matter may be high, in which case the water is often highly-coloured and acid in reaction. Such characters are presented by the waters collected from the surfaces of the igneous, metamorphic (quartz, mica, granite, etc.), Cambrian, Silurian, and Devonian rocks.

The waters from the surface of the non-calcareous carboniferous rocks (Yoredale rocks, millstone grits, and coal measures) are very similar; but those which have flowed over the surfaces of the calcareous carboniferous rocks—the mountain limestone and limestone shales—differ from the former in possessing a moderate degree of hardness, higher total solids, and a neutral or faintly alkaline reaction. The mineral solids consist chiefly of sulphate and carbonate of calcium and magnesium.

Surface waters from the lias, new red sandstone, magnesium limestone, and oolite may vary considerably in their composition. The total solids are generally between 10 and 20 parts per 100,000, the total hardness between 10 and 15 parts, the chlorine is below 2 parts per 100,000, and the nitrogen as nitrates below 0·2 of a part.

Clay waters are, as a rule, opaque, from a variable quantity of suspended matter, but generally there are few dissolved solids, and the water is fairly soft. They vary, however, greatly in their composition. The waters collected from cultivated land present great variations in composition, and the total hardness may range from 5 to

20 parts per 100,000, according as to whether the soil is non-calcareous or calcareous. Alluvium is generally a mixture of sand, clay, and organic matter; and waters from such a source generally contain high mineral solids (50 to 100 parts), consisting of calcium and magnesium salts, sodium chloride, iron, and silica.

2. *Waters from a Depth.*—Those collected from the chalk are generally clear, bright, and well charged with carbonic acid. The total solids are generally from 25 to 50 parts per 100,000, and the total hardness from 20 to 40 parts; the hardness is mostly temporary, and calcium carbonate may vary from 10 to 30 parts. The chlorine is commonly from 2 to 3 parts, but it may reach a higher figure in some pure chalk waters. The nitrogen as nitrates is below 0·5 part per 100,000, and is commonly about 0·2. Sulphates are present in small quantity, and there is often a trace of phosphates and of iron. Although the carbonic acid present is often sufficient to turn blue litmus red, when this is driven off, an alkaline reaction is invariably obtained.

Waters from the oolite present characters very similar to those from the chalk.

Those derived from limestone and magnesium limestone formations only differ from the chalk waters in generally containing more total solids, far more calcium or magnesium sulphate (which may reach nearly 20 parts per 100,000), and less calcium or magnesium carbonate, and by consequence the hardness is to a greater degree permanent.

In dolomite districts the mineral solids contain much magnesium carbonate and sulphate, and a large proportion of the total hardness is permanent, dolomite being a double carbonate of lime and magnesia.

The greensands are porous strata containing a reducing

salt of iron, which by reducing oxidized nitrogen to ammonia often furnishes to the water a very high figure of free ammonia. The total solids vary considerably, but they sometimes approach 100 parts per 100,000 where the water is collected at great depths from greensand underlying the chalk; the chlorine may reach a figure of from 4 to 14 parts; the total hardness (much of which is permanent) is very variable—from a low to a high figure; and the nitrogen as nitrates is generally from about 0·3 to 0·6 part per 100,000.

Waters from red sandstone strata vary considerably in their composition, according as the deposit is pure or impure, soft or hard. The total solids and total hardness are both sometimes high, and the former may reach 100 parts per 100,000; the latter is mainly of a permanent nature, but the water may sometimes be soft, and possess a total-hardness figure not exceeding 10 parts per 100,000. The chlorine may vary from 2 to 6 parts per 100,000; and traces of phosphates are always to be detected in the mineral solids, which mainly consist of sodium chloride, carbonate, and sulphate, calcium and magnesium carbonates and sulphates, and a trace of iron.

Waters from selenitic deposits are often harmful to drink, on account of the large proportion of calcium sulphate (10 to 30, or more, parts per 100,000), which is taken up from the deposit, this consisting of calcium sulphate in clear crystals.

Waters collected from loose sands are of variable composition. Some are soft, with total solids of from only 6 to 12 parts per 100,000, and others are rather hard (permanent) with mineral solids amounting to even 100 parts per 100,000. The chlorine figure is generally rather high, and may amount to a high figure in some cases. The mineral solids consist of sodium

chloride, carbonate, and sulphate, calcium and magnesium salts, and traces of iron and silica. Those from gravel are generally soft, but some are hard, with high total solids.

Waters coming from a depth in the lias clays have generally very high mineral solids (often consisting largely of calcium and magnesium sulphate). There is, as a rule, considerable opacity, and the physical characters generally are not favourable to the water. The hardness, which is almost entirely permanent, is generally over 20, and the mineral solids may reach 300 parts per 100,000.

Deep wells, when protected from surface drainage in their upper parts, are but rarely polluted, even when situated in the centre of towns. But it does occasionally happen that liquid soakage from sewers or cesspools finds its way into fissures in chalk or sandstone, which conduct it to the water of the well, unfiltered and therefore unpurified, and pregnant with danger to the consumers. Deep wells in Liverpool and other places have been closed for this reason.

The following facts will be found of value in seeking for water. In comparatively flat districts, trials should be made by Norton's tube wells at the lowest sites on the survey. The part most covered by herbage is probably the site where the water reaches nearest to the surface. The same fact is sometimes denoted by localised early morning mists or swarms of insects. The nearer the sea, the more likely is water to be found, but if too near the sea the water may be brackish.

In hilly country a search should be made in the deepest valleys, especially the side of the valley towards the highest hill, and at the junction of two long valleys. If there is any evidence of an original watercourse at

this point, water is often found at no great depth. A knowledge of the dip of the strata in the district, and the situation and area of their outcrop, is of the greatest value in such an investigation.

Quantity.

The water supplied to a community must be good in quality and abundant in quantity. Impure waters are liable to cause injury to the health of those who drink them; whilst deficiency of water means want of cleanliness, with its ensuing discomfort and dangers.

Water is required for the following purposes and in the undermentioned quantities for each (representing average requirements):

		Gallons per head daily.	
Household	Fluids as drink	0·33	
	Cooking	0·75	
	Personal ablution	5·00	
	Utensil and house washing	3·00	
	Clothes washing (laundry)	3·00	
	Water closets	5·00	17·08
Trade and Manufacturing		5·00	
Municipal	Cleansing streets Public baths and fountains Flushing and cleansing sewers Extinguishing fires	5·00	
Total		27·08	

The quantities of water given above as required for the household are those which are necessary to maintain a good condition of cleanliness. The 5 gallons for personal ablution would allow a daily sponge bath for

each person. If each person has also a weekly general bath of from 30 to 40 gallons, 5 gallons extra per head daily must be added.

In towns, 5 gallons per head daily is found to be ordinarily sufficient for municipal purposes : and the same amount is required besides, on the average, for manufacturing and trade purposes. Water is also required for animals—drinking, washing, and cleansing of stables. About 16 gallons daily for each horse, and 10 gallons for every cow, are average requirements.

On the whole, it may be said that not less than 30 gallons per head daily of the population should be supplied to every town. There will always be some waste in households from leaky taps and fittings, and this must be provided for. The greater part of the waste, however, very often takes place from the mains, before the water reaches the consumer. In some towns it has been found that as much as one-half or two-thirds of the total water supply leaks out of the mains into the soil.

The amount of water actually utilised in the houses of a town varies enormously. In the houses of the poor it may be only 2 or 3 gallons per head daily. This meagre amount is not only, or even principally, due to want of personal cleanliness amongst the occupants, but is far more often due to the limited quantity of water at their disposal, when the supply is intermittent and has to be stored in cisterns or water-butts, often of a size totally inadequate to the wants of the people who take their water from these receptacles.

The supplies per head in the various towns in this country vary greatly. London is said to have a supply of from 35 to 40 gallons per head daily ; Glasgow has

50; Norwich, $14\frac{1}{2}$; but it must be remembered that these are not the quantities available to the consumers; for the amount lost in leakage through the mains is generally a considerable proportion of the whole supply, and is nearly always an unknown quantity. The adult human being consumes daily about $2\frac{1}{2}$ pints of water as drink, and about another 2 pints in his solid food.

Distribution.

The system adopted by the ancient Romans for conducting the water collected at the gathering grounds into their cities was the construction of masonry aqueducts built on arches, with a gentle incline to allow of a steady flow of water from its source to its outflow in the city. The aqueducts usually crossed the valleys on raised arches, but the Romans also knew how to construct inverted siphons of lead piping for the passage of the water across valleys. The remains of the reservoirs with which the inverted siphons were connected on either side of a valley are still to be seen in the neighbourhood of Lyons.

The water supplied by public companies to towns in this country is now usually distributed from their reservoirs through iron pipes laid underground. These cast-iron mains are subject to much rusting and corrosion, especially when the water is soft. Many of these pipes have been found much weakened by corrosion at some places, and nearly blocked with accumulated rust at others, the water also being deteriorated in quality. It is now usual to coat these pipes with some material which is unacted on by water, such as hot pitch or coal-tar (Angus Smith's method), or with a vitreous glaze. The magnetic oxide of iron produced on the surface of

the metal by Barff's process is also coming into use. In this process the iron pipes are heated to a white heat, and then exposed to superheated steam for several hours. The practice of caulking the joints of these pipes with tow or gaskin next the interior of the pipe, and then running the joint with molten lead, was strongly condemned by the Rivers Pollution Commissioners, as the water absorbs impurities from the tow and hemp. They recommended that the pipes should have turned and bored joints, or, in the case of mains large enough for a man to enter, that the inside of the joint should be pointed with Portland cement. The mains should have scouring valves at their dead ends, and should be placed at a minimum depth of 3 feet, so as to be protected from frost and sun. All the service pipes of the house must also be protected from extremes of temperature, but they should always be left accessible, and if concealment is necessary, it should only be by a removable wooden casing. On freezing, water expands, and the pipe may burst; but as the fracture is not discovered until the thaw sets in, there is a popular impression that the thaw is the cause of the pipe bursting.

An enormous amount of leakage takes place from water companies' mains in many towns, from slight settling of the ground after laying, or from the vibration of heavy traffic causing fracture of the pipes and joints. It has been estimated that in London 15 gallons out of the 35 supplied per head daily thus run to waste in the soil. The loss is especially great where the supply is constant and the mains always kept under pressure. If the spots at which leakage occurs could be known, the pipes could be easily taken up and repaired, but the difficulty is to find where the leaks are. This difficulty has been overcome by Mr. Deacon, who has invented a

meter which can be used as a waste-detector. One of these meters is placed on each district main ; it registers the flow of water by day and night, and therefore the waste, for the water flowing through the main during the dead of night is not used by the consumers, but is running to waste. Having localized the waste to the district supplied by a district main, the exact spots where the leakages are taking place can be determined by the vibrations thereby produced in the nearest house communication pipes, which can be distinctly heard on applying the ear to the pipe. By this system, to take one example only, the Lambeth Water Company has reduced its consumption from 34 gallons per head per day to 20 gallons, the quantity available to the consumer remaining the same.

The house communication pipes in nearly all towns are of lead, connected with the main by a brass screwed ferrule. Lead house service pipes are employed, because the ductile metal can be easily bent as occasion may require in carrying them through a house, and they are easily jointed and rustless. If wrought-iron pipes are used, double screw joints should be provided at convenient points to admit of the clearing away of the rust, which often chokes an unprotected iron service pipe. It has been thought that lead pipes would be acted on by water, especially soft water, and that there might be danger to the consumers. Such has not been found generally to be the case, for although new lead pipes are undoubtedly acted on by soft water, an oxide of lead being formed which rapidly dissolves again, yet even in the case of peaty waters there is often a deposit of vegetable matter as well, which prevents all further action of the water upon the metal. The Loch Katrine water acts most powerfully on lead, and yet no symptoms of lead-

poisoning have ever been observed amongst the population of Glasgow.

The hard waters, which contain salts of lime and magnesia, either have very little solvent action on lead, or they quickly coat the metal with the basic carbonate or sulphate of lead, which prevents further action. The soft, highly oxygenated waters containing organic matters, peaty acids, nitrites, nitrates, and chlorides, are those which have the most powerful action on lead, the oxide of lead which forms upon the surface of the metal being constantly dissolved and carried away in the water. Where lead-poisoning is feared, a block-tin pipe or a coated cast or wrought iron pipe should be substituted for the lead pipe. Block-tin pipes enclosed in lead pipes are occasionally used ; it is important that there should be no crack or fracture of the tin lining, otherwise galvanic action will be set up when the pipe is full of water, and large quantities of lead will be dissolved. Polluted shallow-well waters have been known to have a very powerful and persistent solvent action on lead, probably from their containing excess of carbonic acid, which tends to dissolve the coating of carbonate of lead formed in the pipe or cistern.

It has been suggested that the varying powers of corroding lead, exhibited by soft waters of apparently identical chemical composition, are influenced by the presence or absence of silica in the water. When silica is present, even in the proportion of only half a grain per gallon, the action on lead is said to be very slight. There must be no excess of alkali in the water, or this inhibitive action of silica is not displayed. By passing distilled waters and other soft waters known to have a corrosive action on lead through a filter formed of layers of sand, broken flints, and granite, enough silica is taken

up to reduce the lead-corrosive power to one-thirtieth. Recent experiment, however, seems to show that the alkaline carbonate, which may be taken up from the limestone, may be an even more important factor than the silica. The waters of Huddersfield and Sheffield, which have a considerable effect on new lead, have been rendered nearly inactive by passing them through filters constructed as above. Some of the solvent properties of these waters are believed to be due to the presence of peaty acids (humic, ulmic, etc.), and if the acidity is thus neutralized the plumbo-solvent action of the water is much reduced. After the prolonged drought of 1887, the waters in the Sheffield reservoirs ran very low, the peaty acids—derived from the gathering-grounds—were not diluted to the usual extent, and a severe outbreak of lead-poisoning occurred in the town. In other cases the acidity which gives the water its lead-dissolving powers may be due to the presence of free sulphuric acid formed by oxidation of iron pyrites. It has been suggested by Mr. Power, in a report to the Local Government Board, that the biological characteristics of a water—the presence or absence of bacterial organisms—may exercise an influence over its "plumbo-solvent" properties. There is also some evidence to show that leaden pipes are much more rapidly corroded when the mains are intermittently charged, than when kept under constant high pressure.

Water companies supply water to their customers either on the constant or the intermittent system. Under the former, the aim is to keep the mains constantly charged with water under pressure, so that, the house pipes being also always charged, no storage of water on the premises of the consumer is required. The only cisterns which should be required in a house supplied with

a constant service of water are small cisterns or water-waste preventers for flushing water-closets, and a small cistern to supply water to the kitchen boiler. Under the intermittent system, the flow of water in the mains is stopped, except for a short period of every day, by the turncock. The house pipes are only charged when the water is flowing in the main, and consequently water must be stored for use on the premises when the pipes are empty. The merits and drawbacks of each system we will now proceed to consider.

The great fault of the *intermittent service* is that water must be stored on the premises of the consumer. Water stored in small receptacles, even under the most favourable circumstances, deteriorates; it loses its aerated character, becomes flat and insipid, and collects impurities from the air. In the houses of the poor, water is often stored in the most filthy receptacles — wooden butts and tubs rotten and decayed within, or in cisterns exposed to the air, which are the receptacles of all sorts of filth and rubbish. The situations in which cisterns are often found on such property are the immediate vicinity of the w.c., and beneath landing floors, staircases, or even bedroom floors. Even in the better-class houses cisterns are often placed in the most improper places, as under stairs or floors, where dust and dirt fall into them, or inside water-closets, where the air is loaded with foul gases.

The same cistern is far too frequently used to flush water-closets as well as to supply the drinking water, which may become dangerously polluted in this way (see Chapter II.).

Another method, by which drinking water in cisterns becomes liable to a very dangerous pollution, is the practice—now, fortunately, but seldom seen—of con-

necting the "standing waste" or overflow pipe of a cistern with a drain or soil pipe of the house, or with the D trap under a water-closet. It may be that the overflow pipe has a ⊔⊓ bend on it before its junction with the drain, but as the water in a trap quickly evaporates when not renewed—and the water in this trap can only be renewed if the ball-cock of the cistern leaks—little obstacle is presented to the passage of foul air from drain, soil pipe, or D trap, up the overflow pipe, where it escapes over the water of the cistern (see Chapter II.).

Besides the danger of pollution of water in cisterns by sewer air, dust, soot, and accidental contaminations such as dead mice, birds, or cockroaches, the material of which the cistern is composed is an important factor as regards the purity of the water stored in it. Iron cisterns rust and discolour the water; zinc in small quantities is occasionally dissolved by water; lead is dissolved at first when the cistern is new, but rapidly becomes coated with carbonate or sulphate of lead when the water is hard. The deposit forms a lining which protects the surface of the metal from further action, and it is for this reason that the inside of a leaden cistern should never be scraped when the cistern is being cleaned out. Galvanized iron is largely used for cisterns; they are generally perfectly safe, but have been known to give up a trace of zinc to the water. Wrought-iron cisterns covered with a vitreous enamel may also be safely used. Slate is a good material for cisterns, but the cemented joints must not be repaired with red lead when they leak, as they often do; for both white lead (a mixture of carbonate and oxide) and red lead (an oxide) are soluble in water. Stoneware and fireclay cisterns, though heavy, are very valuable, as they give up nothing to water and no joints are necessary. Water should never be left in contact

with wood, as wood, when constantly wet, rapidly rots, and forms a breeding-place for minute worms and other animal organisms.

To indicate briefly the conditions under which water may be safely stored in houses: (*a*) The cistern should be of stoneware, slate, or galvanized iron; (*b*) it should be placed in a light and well-ventilated position, and should be properly covered; (*c*) it must not be used to flush water-closets, but may supply the "intercepting" or waste-preventing cisterns which should be used for this purpose; (*d*) the overflow pipe must be carried out into the open air to terminate as a warning pipe; (*e*) the cistern should be cleaned out at least once in every three months.

Cisterns are occasionally used to supply water-closets which have regulator valves on the supply pipes near to the basin. Although there is but little danger by this arrangement of foul air finding its way into the drinking water of the cistern, as the supply pipe is always full of water unless the cistern is empty, still, it is better to break the connection altogether between drinking-water cisterns and water-closets.

Another disadvantage of the intermittent service is that the capacity of the cistern is often utterly inadequate—especially in poor houses—for the wants of the people who depend upon it as their only source of supply. So great is this deficiency of storage capacity in many parts of London, that the water companies erect stand-pipes in courts and alleys, which are connected with a main always under pressure.

The advantages of an intermittent over a constant service are that there is less waste inside houses, and that the service of pipes, taps, and fittings need not be so strong as for a constant service. This latter point has

been disputed, as regards the pipes, on the ground that there is a greater strain on the pipes where the water is suddenly turned on or off with a common stopcock, than where it is slowly turned on or off by the screw-down tap used with a constant service; but it must be remembered that with a constant service the water in the house pipes is under a much higher pressure than where the pipes are connected with a cistern in the house. There is no danger, either, with an intermittent service of the higher parts of the town being without water on account of great waste in the low-lying parts, as sometimes occurs with a constant service.

A merit often claimed for the *constant service* is that no storage is required on the premises of the consumer. The water drawn from the taps on the house pipes is clear, cool, and sparkling, in the same condition as it leaves the water companies' mains, and the supply is—or should be—abundant and never-failing. But experience has shown that it is generally desirable to retain or provide some means of storing water on the premises, to meet requirements when the supply is cut off on account of repairs to the main or by frost.

It has been suggested that the shape of the cistern in common use should be modified to that of a cylinder, ending below in an inverted cone, with a draw-off pipe at its bottom to admit of the flushing away of any deposit which accumulates; the service pipe from the cistern to be soldered into the side like the present overflow pipe, but of course lower down, and the lid to be tightly fitting.

In actual practice in many cases, the advantages of a constant service have been somewhat mitigated by errors on the part of both consumers and water companies. Unless constant inspection is exercised, and the taps and fittings in houses frequently supervised, there is great waste.

This occurs especially in cases where an intermittent service has been changed to a constant service, and the old pipes and fittings have been retained. The company, to economize water, shut it off from the house pipes, and then no water is obtainable perhaps for many hours.

Not only this, but where water-closets are flushed by a pipe and tap direct from the house main, without the intervention of a cistern or water-waste preventer—a not unusual occurrence in poor neighbourhoods—there is great danger of foul air, or even liquid filth, being sucked up into the empty pipe when the tap is left unscrewed, and so finding its way into the water mains of a district. The suction is due to a partial vacuum being created in the water mains when the water is turned off, owing to the water finding its way through leaky joints into the soil, or from the mains being emptied by taps on house pipes at a lower level. Such occurrences have given rise to epidemics of enteric fever at Croydon, Cambridge (Caius College), Sherborne, and other places. They illustrate the absolute necessity of breaking the connection between water-closets and water mains by the interposition of a small cistern or water-waste preventer.

In other cases the companies try to economize by insisting on the insertion of a throttle of very small diameter ($\frac{1}{8}$ to $\frac{1}{16}$ inch) into the house communication pipe, with the result that water merely dribbles out of the house taps when they are full on. In any case, screw-down taps must be substituted for common taps, and a screw-cock must be placed on the house pipe, where it enters the premises, to shut off the water in case of a pipe bursting. A drip-tap should also be placed on a pipe at the lowest part of the system, by which it may be emptied during frost. All the leaden service

pipes of a house should be strong (12 pounds per lineal yard for 1-inch pipes, and 6 pounds per lineal yard for $\frac{1}{2}$-inch pipes), in order to withstand the constant pressure to which they are subjected. If pressure is maintained in the mains by pumping, and not by storage in a high-level reservoir, greater power must be used in the morning of every day, this being the time when the largest quantities of water are drawn for domestic use. The difficulties in the way of the adoption of a constant service are doubtless great, but they—especially great waste of water—can be overcome by the use of Deacon's waste-water meter on the district mains, and by frequent supervision of house taps and fittings. The supply of water by meter would tend greatly to check waste, but is not advisable in the case of poor populations, as the inevitable stinting of water that would follow would have great sanitary disadvantages. For trade purposes it is the most just and reasonable method. Water-meters are either "positive," and indicate by the number of times a cylinder of known capacity is filled, as shown on a dial; or they are "inferential," when the amount of water which has passed through them is inferred from the velocity of the flow, as registered on a dial.

There is one danger to which water mains are subject, which has not yet been alluded to. If water mains and sewers are laid in the same trench, there is a possibility of foul matters, which have escaped into the soil from leaky sewers, being sucked into the water mains, if these are in any way defective, during intermissions in the service. In a similar manner, too, water mains may suck in from the surrounding soil coal gas which has escaped from leaky gas pipes and mains, for experiments prove that there is a partial vacuum at defective parts in pipes even when they are running full bore. Such intermissions

are the daily occurrences of an intermittent service, and are often unavoidable with a constant service for executing necessary repairs to the pipes. The water and sewerage systems should be kept as far apart as possible.

With a constant service the mains are always charged in case of fire ; with an intermittent service much valuable time is often lost in finding the turncock.

Purification of Water.

It is highly desirable that the water-supply of a community should, as far as possible, be free from all foreign and polluting ingredients. Nearly all waters derived from natural sources contain such ingredients, and the various processes of purification aim at their elimination. The foreign ingredients may be divided broadly into mineral and organic matters. As we have seen, most of the spring and deep-well waters, many shallow-well waters, and to a less extent the various river waters, contain the salts of lime and magnesia, which render these waters hard. The removal of these salts, and the production of softer water, is eminently desirable for economic purposes, and occasionally to improve the potability and wholesomeness of the water when the salts are in great excess, or are chiefly of the kind producing permanent hardness. The removal of the organic matters, suspended or dissolved in water, is another and still more important object in any process aiming at complete purification. We shall now proceed, first, to the consideration of those processes which are, or could be, undertaken on a large scale for the purification of water before its distribution to the consumers ; and, secondly, to such processes of domestic purification as may be undertaken on his own premises by the consumer, who has received his water

from a public source, but is not satisfied with its quality, and desires if possible its still further purification.

What should be aimed at, however, is to procure at its source a water sufficiently good to require no artificial purification; but failing this, the water should be efficiently purified before its distribution to the consumers. It is certainly not wise to leave the purification to individual initiative.

Purification on a Large Scale.—There are several processes (Clark's, Porter-Clark's, Maignen's, Howatson's, etc.) which aim at the removal of the mineral matters (the salts of lime and magnesia) from a water. The fundamental basis of them all is the addition of lime water. When a certain quantity of lime water is thoroughly mixed with a hard water, it combines with the carbonic acid holding the chalk in solution as calcium bicarbonate, with the result that the new carbonates thus formed are precipitated, for they are practically insoluble in water. In this way chalk well waters of 20° of hardness may be reduced to 4° or 5°, and Thames water (16°) to 3° or 4°. The hardness thus got rid of is due to the precipitation of chalk, and chalk alone; it is temporary hardness, and the same effect would be produced on the water by sufficient boiling.

The working of the process (Clark's) may be described shortly as follows:—For Thames water the proportion of lime to be used should be about 14⅓ cwt. to each million gallons. The lime in the form of quicklime is first slaked with water in a tank, into which the water to be softened is gradually allowed to flow; thorough mixing must be insured by wooden paddles or other mechanical means. The water becomes milky in appearance from precipitation of the chalk, and must then be allowed to settle for twelve hours, and subsequently be decanted. Besides

chalk, a certain amount of colouring and organic matters are removed from the water by this process. It is important that uncombined lime should not pass out with the purified water, as would be the case if lime were added in excess of that required to combine with all the carbonic acid holding the chalk in solution. To detect uncombined lime, it is only necessary to add a few drops of a solution of nitrate of silver to the treated water in a shallow white dish, when a yellow or brownish colour is produced if uncombined lime is present, but only a white precipitate of chloride of silver if there is none present.

Lime is also used as the precipitating agent in Porter-Clark's process; but the suspended particles of chalk are removed, not by settlement, but by filtration through a series of linen cloths in a filter press under high pressure. The plant includes two vertical cylinders and a filter press. In the first cylinder there is a continuous preparation of lime water, which is mixed in the second cylinder with the hard water. The precipitant formed is then separated by the press. The process is expeditious, and very effective in removing lime and suspended matters from the water. It is one of the best means of softening water on a large scale.

In Atkins's process, which is somewhat similar, arrangements are made for cleansing the cloth filters by means of revolving brushes which play on the surface of the discs.

The Stanhope Water-softener aims at reducing both the temporary and permanent hardness, lime and soda being used. The caustic soda somewhat reduces the permanent hardness by converting some of the calcic or magnesic sulphates to sulphate of soda. Clarification is effected by subsidence in high tanks containing numerous funnel-like shelves, one above the other, which collect the deposit and direct it to the bottom of the tank.

Howatson's process is very similar. In this process the deposit is removed by opening valves in the hopper bottoms of the tanks.

In the Maignen Automatic Softener a small motor is worked by the water and regulates the amount of *anticalcaire*, which mixes with the water in a small tank. Sedimentation takes place in a second small tank, and finally the water passes through a *filtre rapide* into a storage tank. The precipitating agent, *anticalcaire*, contains lime, sodium carbonate, and alum.

The Lawrence process of softening and sterilizing water is ingenious and effective. In this apparatus the water is boiled, and therefore softened and sterilized ; the steam is condensed by the cold water entering the boiler, which takes up the heat from the steam, and thereby an important economy is effected in the heat required.

The process of filtration through *sand* or *gravel* on a large scale, as carried out by the London water companies, has already been described (see p. 18). Suspended matters, both mineral and organic, are very effectually removed by sand filtration.

Spongy iron, which is porous metallic iron, obtained by roasting hæmatite iron ore, has a very similar action on dissolved organic matters in water to that exerted by *magnetic carbide of iron ;* and, like magnetic carbide also, it yields nothing to water except a little iron, which may be removed by subsequent filtration through sand. Spongy iron retains its properties for a long period, but requires periodical renewal, especially when used, as it generally is, as a mechanical filter for separating suspended matters from water, as well as a chemical filter. Spongy iron separates lead from water, but has no effect on other mineral matters.

The property possessed by spongy iron and the mag-

netic carbide and oxide of iron of yielding nothing to water —no phosphates or other germ nutrients—is a most valuable one ; for the water after filtration can be stored for any length of time without any great deterioration from growth of microscopic organisms. The especial fitness of the magnetic carbide of iron or of *polarite* for filtering a town water-supply on a large scale lies in the fact that, when once the beds of these materials are *in situ*, they need never be disturbed or renewed, and thus an enormous amount of labour and expense is avoided. The aeration by intermittent filtration, which is essential for magnetic carbide of iron, if it is to retain its oxidizing properties, must not be practised with spongy iron, as the latter cakes on exposure to the air.

At Antwerp and other places on the Continent scrap-iron (Anderson's process) is now being used for filtering water on a large scale. The scraps of iron are placed in a cylinder, which is caused to revolve on its long axis. The inner circumference of the cylinder is provided with short curved shelves reaching from end to end, which, when the cylinder is revolving, serve to direct a shower of iron through the water as it passes through the apparatus. The water is then exposed to the air by flowing along a trough, so as to cause a precipitate (as ferric oxide) of the iron taken up in the revolving cylinder, and this precipitate as it settles carries down organic matter with it. The precipitate is subsequently removed by filtration through sand.

Domestic Purification.—Distillation effects a more complete purification of water than any other method which is practised. If the first portions of the distillate, containing volatile substances present in the water to be distilled, are rejected, a water free from all foreign ingredients is obtained. Its aeration, however, is deficient ;

but this aerated quality can easily be acquired by allowing the water to flow out of fine holes in the bottom of a cask, and to pass through the air in finely divided streams. The distillation of sea-water is now largely carried out on board the ships of H.M. Navy and in the large steamships of the mercantile marine. As long as there is fuel on board, a most wholesome water can be obtained. Distilled water acts very readily on metals such as copper, zinc, iron, and lead; so it is important that the several parts of the distillation or condensing apparatus should not expose these metals to the action of the water. Silver-lined or block-tin vessels and pipes may be used.

By *boiling* water, carbonic acid is driven off with other volatile gases dissolved in the water, and chalk (temporary hardness) is deposited at the bottom of the vessel. The water is therefore softened. We have the strongest reason for believing that distillation and boiling—raising the temperature of the water to 212° F.—effectually destroy all organized living matter in the water. There can be little doubt but that the specific poisons of cholera, enteric fever, and of other diseases, occasionally propagated by means of impure drinking water, are effectually destroyed by even a few minutes' boiling. The spores that resist the temperature of boiling water are, seemingly, not disease germs, but merely the immature forms of harmless species; for experience has shown over and over again that water, and other fluids mixed with water, such as milk, in which the existence of poisons capable of producing enteric fever, cholera, scarlet fever, or diphtheria, was almost undoubted, have been rendered harmless by a few minutes' boiling.

To completely sterilize water or any other fluid, it is necessary to boil it, or merely raise the fluid to a temperature of 212° F. without actual ebullition, for a short

period (half an hour) on three or four successive days. In this way the spores, which escape destruction by the first boiling, have time to develop into adult bacteria, which are destroyed by the next boiling, and so on, until all the successive crops are disposed of. Boiled water is flat and insipid, and should be aerated before being drunk.

Alum is sometimes employed as a purifying agent. It is much used in China, where the turbid waters of the large rivers are extensively drunk after the addition of a little alum. When added to water containing chalk in solution, it forms a bulky precipitate of aluminium hydrate, which falls to the bottom, carrying with it suspended and floating matters. It has little or no effect on organic matters in solution in the water. About 6 grains of alum to the gallon of water is the right proportion.

Filters.—Domestic filters are probably more often a source of pollution of the water than otherwise. It is usually considered that a filter requires no attention: it is consequently but rarely cleaned; the filtering material is seldom renewed, and its pores become clogged with putrescible organic matters, which form a suitable nidus for the growth and development of the living organisms that contaminate the filtered water. It is not unusual, under such circumstances, to find a considerably larger proportion of organic matter in the filtered water than was present before filtration.

This is especially the case when *animal charcoal* is used as the filtering material. This substance is prepared by calcining crushed bones in closed vessels; it is extremely porous, and exerts considerable oxidizing action on dissolved organic matters in water, and bleaches colouring matters in solution. These properties, however, are evanescent, and rapidly disappear if the charcoal is not cleaned or renewed, especially if the water filtered through

it is somewhat impure. Not only this, but the charcoal yields to water phosphate of lime, of which it is largely composed. The phosphate favours the growth of living organisms, so that water must neither be kept too long in the filter, nor must it be stored for use after filtration. Animal charcoal has very little action on fresh egg-albumin : it has been reasoned from this circumstance—and, as now known, with correctness—that animal charcoal does not prevent the passage of living disease germs through its substance. For these reasons filters composed of animal charcoal, whether in loose fragments or in compressed blocks, are not at all suited for domestic use. They require more care and attention than any domestic filter is likely to meet with. These filters have the power of removing lead from water if their surfaces are kept constantly clean by frequent scrubbings ; this is probably due to the lead forming a phosphate in the filter.

Silicated carbon and *manganous carbon* block filters are still largely used. They consist of animal charcoal compressed into blocks by admixture with silica or manganese. They do not yield so much phosphate of lime to water as the pure animal charcoal filters, but they tend to become coated with a layer of organic matter which clogs the open pores. The block should be brushed occasionally to remove the thin film coating it ; and every three months, at least, should be purified by subjecting it to a red heat, or by boiling it in a solution of Condy's fluid and sulphuric acid. *Maignen's Filtre Rapide* consists of a strainer of asbestos cloth spread over a perforated porcelain cone. Powdered animal charcoal, or other filtering medium, is laid over the strainer. The delivery of water through this filter is very rapid, and the asbestos and powder can be easily renewed at very small cost.

Domestic filters are also made of *spongy iron*, *magnetic carbide of iron*, *polarite*, and *carferal*, this latter substance being a mixture of iron, charcoal, and clay. It has good oxidizing properties, and yields nothing to water which is favourable to organic life; but its lasting powers are inferior to spongy iron and magnetic oxide and carbide.

In Bischoff's spongy iron filter the iron ore rests upon a layer of pyrolusite (a crude oxide of manganese), and the outlet to the filtered water receptacle is generally protected by a layer of asbestos cloth.

With regard to filters of the kind alluded to above, which afford no protection against the infection of water-borne disease, Drs. Woodhead and Wood point out that they may materially increase the risk to the consumer of acquiring such infective diseases, inasmuch as the specific organisms of these diseases become arrested in the filtering materials, and may then be washed through in great numbers into the filtered water for many days subsequent to the introduction of infected water into the filter. If, for instance, the water-supply of a house received a chance contamination, which rendered it dangerous for one day only, the consumption of the water involves the risk of specific infection on that day only; but should the polluted water be passed through a domestic filter of the kind indicated, the arrest of the specific microbes in the filter, and their subsequent passage into the filtrate, would render the water passed through the filter liable to convey infection for several days after the initial introduction of the pollution. The consequent multiplication of the opportunities of infection necessarily greatly increases the risk of such an occurrence. The wrong and misleading statements set forth so prominently by the makers of such filters, as to their capacity to render any water, however polluted, harmless and innocuous, give rise to a false sense of

security in the minds of the public, and are an evil which should be strenuously combated.

In the *Pasteur-Chamberland* filter the water, under pressure, is passed through five or six hollow cylinders of a specially prepared form of porous porcelain. The filtered water is entirely freed from all suspended matters, including all kinds of bacterial organisms and their spores. The water is therefore *sterilized;* but, the filter acting merely mechanically, there is no alteration in the chemical composition of the dissolved constituents of the water. This filter is employed to sterilize pure waters for laboratory purposes, and may with advantage be so used for domestic purposes. The bottom of the filter is connected with a main under pressure, the water issuing from the top. These filters require periodical cleaning at short intervals, to remove deposits on the surface of the porcelain; otherwise the delivery of water is much reduced.

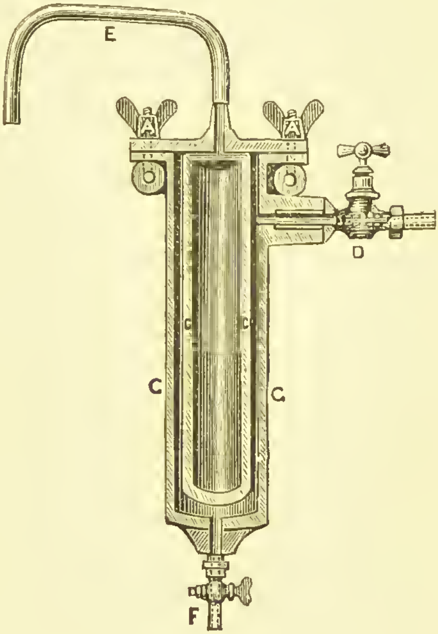


FIG. 4.—BERKEFELD FILTER.

AA, Screws for joint to open filter case for removing filtering cylinder for cleaning, etc.; E, outlet for filtered water, which can either be fixed or simply placed on the protruding metal end of the cylinder; CC, filtering cylinder; D, tap union to attach to water service; F, flushing tap to wash out filter or to supply unfiltered water.

The *Berkefeld* filter is similar in principle to the above, but the hollow cylinder, through which the

water is filtered, is composed of a compressed siliceous or diatomaceous earth called Kiesselguhr (Fig. 4). It permits of more perfect cleansing, but is more fragile than the Pasteur-Chamberland filter.

The experiments of Drs. Woodhead and Wood show that the Berkefeld table filter completely arrests specific disease organisms, but that, like the Pasteur-Chamberland and the Porcelaine D'Amiante to a lesser degree, it allows water organisms usually present in water to grow through the filtering material, with the result that they appear in the filtrate on the third day after introduction. It does not, therefore, continuously sterilize. The Porcelaine D'Amiante filter, in which the clay is mixed with finely-powdered asbestos, is the best sterilizer, but in it the rate of filtration is so slow, that it is unfitted for domestic purposes.

Filters should never be placed inside cisterns. In such positions they are neglected, their very existence being sometimes forgotten, with the result that they become excessively foul, and pollute the water they are intended to purify.

From what has already been said, it will be seen that the essentials of a good filter are—that every part should be easily accessible for cleansing purposes; that there should be nothing in the construction of the filter which is capable of yielding metallic or other impurities to the water; that the filtering medium should be efficient for the work in hand, and its purifying power reasonably lasting; and that the delivery of filtered water should be reasonably rapid.

DISEASES PRODUCED BY IMPURE WATER.

Dyspepsia and Diarrhœa.—Waters with permanent hardness exceeding 7° or 8° sometimes cause dyspeptic symptoms and diarrhœa, especially amongst those who are not used to them. Similar symptoms are generally produced by drinking brackish water drawn from wells near the sea-coast. The injurious salts are especially the sulphates of magnesium, calcium, and sodium and the chloride of magnesium. Particles of suspended clay, mica, or vegetable matter may also cause diarrhœa.

Waters containing calcium carbonate in solution, the temporarily hard waters, are not in any way injurious to health. At the same time, there is no reason to believe that the chalk waters are at all superior to soft waters for drinking. The idea once entertained, that the salts in hard water aided the growth and nutrition of the bones in children, has been abandoned as untenable.

Diarrhœa, often of a severe choleraic type with violent purging, vomiting, and cramps, is occasionally produced by drinking water contaminated with sewage. But here, again, it is principally amongst those who are unaccustomed to the water that these severe symptoms occur. Instances have been known where people have gone on drinking filthily polluted shallow-well water for years with no apparent bad effects. It seems, indeed, certain that by long habitude the system becomes tolerant of many substances in water which exert a marked effect on those who drink them for the first time. Whether the choleraic diarrhœa is due to the presence of a living germ in the water, to dead and decayed organic matter in solution or suspension, or to alkaloidal poisons, the products of the growth of bacterial organisms, is not yet certain.

Vegetable matter, such as peat in water, is generally harmless. Large excess of such matters, especially when decaying, may produce unpleasant symptoms.

Infantile diarrhœa, which is so prevalent and fatal in the large towns of this country in the warmer summer months, appears to be due to water pollution in many cases. The polluting material, whatever its nature and origin, seems to be incapable of producing diarrhœa until the temperature of the water stored in cisterns and reservoirs has risen above 60° F. This fact likewise points to the presence of a living organism in the water as the cause of the diarrhœa, an organism which is inactive at low temperatures, but rapidly multiplies and acquires pathogenic properties when a suitable temperature is reached.

The same conditions of drinking water which produce diarrhœa in this country, often give rise to *dysentery* in hot climates. Dysentery may also be spread by the evacuations of patients suffering from this disease contaminating the water used for drinking. Dysenteric evacuations are believed to contain the specific poison of the disease.

Enteric Fever.—This disease is often spread by the medium of water. The conditions of drinking water which are capable of producing dyspepsia, diarrhœa, or dysentery cannot produce enteric fever. Enteric or typhoid fever is a specific disease;* it can only be propagated by a specific poison contained in the secretions and discharges of a patient ill of the disease. It is true that there are some persons who hold that enteric fever is not a specific disease, and that it can arise *de novo*, by

* This view is not shared by some army medical officers; for in tropical climates it is often impossible to connect an outbreak of typhoid with the contagion of a pre-existing case.

which is meant that enteric fever can be produced in man by the introduction into his body of ordinary filth—filth which has not received the specific typhoid evacuations, but which has by a fortuitous combination of circumstances, not known and not understood, acquired the power of producing a disease which runs a definite course, with definite symptoms, and which confers immunity on the person once attacked for the rest of his life. The two strongest arguments against this view are: (1) Many instances have been recorded where people, even whole villages, have drunk fæcally-polluted shallow-well water for years with impunity, until a case of enteric fever imported from without has introduced the specific poison into the water, on which occurrence a widespread epidemic has begun; (2) it is practically impossible, when the origin of an epidemic of enteric fever is in question, to exclude the possibility of the presence of the enteric fever virus in the water or other substance credited with the outbreak. It is now known that the specific poison of this disease may remain latent for considerable periods, until some change in its surroundings and environment calls it again into a state of activity. Cases of the fever which to all appearance have had a *de novo* origin, may have in reality been caused by a latent poison springing again into activity.

Nearly all the evidence we possess points to the possibility of the discharges of a single patient infecting an enormous volume of water.

Although it is now generally believed that the bacillus of typhoid loses its vitality and dies out when discharged into ordinary sewage, it would appear that this is not the case when sewage finds its way out of a sewer, and percolates through the ground. Under these conditions basic nitrates are formed by oxidation of ammonia and

nitrogenous matters, which favour the life and growth of the bacillus of typhoid, and enable it to persist for long periods. This is important in relation to the contamination of shallow wells by the percolation of sewage.

Enteric fever discharges are now believed not to be highly infectious at the moment of excretion ; it is necessary that the virus should be allowed to grow in contact with air before its infectious properties are capable of full development (see Chapter IX.).

Asiatic Cholera.—This is a specific disease, spread by a specific virus contained in the evacuations of a person ill of the disease. There is now abundant evidence that cholera is often propagated by means of drinking water to which the specific disease poison has had access. This is not the only mode of spread of the disease, no more than it is of enteric fever; but the evidence which is constantly accumulating points strongly to the conclusion that as for enteric fever, so for cholera—specifically infected drinking water is one of the most frequent methods of its propagation. In India, the filthy habits of the natives cause a gross and persistent pollution with fæcal matters of the drinking water in the wells and tanks, from which so large a population obtain their entire supply. The evacuations of cholera, like those of enteric fever, are probably not possessed of any high degree of infectiveness at the moment of discharge. The virus requires to grow in contact with air before its higher powers of infectiveness can be developed (see Chapter IX.).

Yellow fever has been traced to drinking water polluted with the discharges of people ill of the disease; but other modes of spread are probably equally potent and more frequent.

Diphtheria is not usually propagated through the

medium of drinking water, but cases favouring such a view have been recorded.

Urinary calculi were at one time supposed to arise from the use of hard water, but this view is now generally abandoned from want of any definite proof.

Rickets has been ascribed to the use of soft water, but the contention is not warranted by facts.

Goitre appears to be due, in many instances, to the water used for drinking, but the impurities in the water which favour hypertrophy of the thyroid gland in some districts are not those found in the water of other goitrous districts. The carbonates and sulphates of lime and magnesia, which are present in the waters of some districts, and have been credited with being the cause of goitre in those districts, are not found in the waters of other districts where goitre prevails. The presence of sulphides of iron or copper in water has been regarded by some observers as the efficient cause of goitre, but not apparently with much reason. On the whole, then, we shall be justified in concluding that the quality of the drinking water, in districts where goitre and its allied disease, cretinism, exist, is only one—and perhaps not the most potent—factor out of many which, in combination, are productive of the disease. Further researches are required to elucidate this question, which is one of great interest.

Entozoa.—The embryos or eggs of the following parasites have been found in water, and may be taken into the stomach of man, when such water is used for drinking. They are: *Tænia solium*, *Tænia echinococcus*, *Bothriocephalus latus*, *Ascaris lumbricoides* (round-worms), *Oxyuris vermicularis* (thread-worms), *Filaria sanguinis hominis*—the embryos of which are sucked from the blood of infected persons by mosquitoes, and, after developing in the body

of that insect, are then transferred to water by means of the larvæ—*Bilharzia hæmatobia*, *Tricocephalus dispar*, and *Distoma hepaticum* (liver fluke of sheep). *Bilharzia hæmatobia* causes endemic hæmaturia in Egypt, Abyssinia, the Cape, etc. The ova are passed with the urine, find their way into water, and hatch into ciliated embryos. *Filaria sanguinis hominis* produces endemic chyluria within the tropics. *Anchylostoma duodenale* causes anæmia, internal hæmorrhages, etc., and occasions great mortality in Brazil, West Indies, and Egypt, where it is thought to be sometimes due to infected water. The embryo guinea-worm, *Filaria dracunculus*, is aquatic and finds its way into the human body through the alimentary canal by means of drinking water, the adult worm being subsequently found in most cases in the subcutaneous tissue of the feet and legs of affected persons; whilst *leeches* may fix themselves in the pharynx and cause much hæmorrhage. Anthrax, hog-cholera, and glanders may all be communicated to cattle through the agency of impure water; and drinking water appears to be the principal media by which the entozoa generally pass from one animal to another.

Metallic poisoning may be caused by pollution of drinking water with refuse from trades and drainage from metalliferous mines, or from absorption by water of the metals used in the construction of distributing pipes, tanks, and cisterns. The amounts of copper, zinc, or arsenic, which must be present in the water to give rise to symptoms of poisoning have not been definitely ascertained; as regards lead, as little as $\frac{1}{10}$ grain per gallon may produce plumbism in predisposed persons. In the case of the poisoning of Louis Philippe's family at Claremont, $\frac{7}{10}$ grain of lead was found in each gallon of water.

The Opinion upon a Water Sample.

Chemical Examination.

Where the water is considerably polluted, no difficulty is experienced in detecting the pollution by chemical analysis, but, generally speaking, the slighter degrees of pollution are detected only with difficulty, unless the "normal" quantities of chlorine, ammonia, etc., in the natural water of the district have been previously ascertained. This arises from the fact that the chemical constitution of the geological formations over or through which water may find its way is liable to variation, and the proportion of chlorides, nitrates, sulphates, phosphates, etc., which the water may take up are thereby affected. It is, therefore, only by establishing "water standards" that the best results can be obtained from chemical analysis, any departure from these standards being regarded as suspicious. A standard based on the amount of chlorine, oxidized nitrogen, and albuminoid ammonia is the safest. For instance, a water sample may easily contain 2 parts per 100,000 of chlorine without any suspicion being aroused; but if the average of the pure water of the locality is only 1·5 parts, then the excess becomes important evidence of "added chlorine," the presence of which would be most significant of animal pollution.

Nitrates and Nitrites.—These are the oxidized residues of organic matters, almost always derived from an animal source (sewage). Their determination is, therefore, a point of the greatest importance, for they indicate either a pollution of the water at some remote period with possibly dangerous ingredients, or the contamination of the water at the present time with partially or completely purified sewage. They are found, often in considerable

quantities, in deep wells or spring waters, and in this case merely indicate the complete purification which the water has undergone in its passage from the surface to the subterranean reservoirs. In the case of shallow-well waters, nitrates and nitrites, if found in association with excess of chlorine and ammonia, indicate soakage of sewage or animal refuse into the well, more or less purified by its passage through the intervening layers of earth. At any time, however, the purifying power of the filtering earth may be exceeded or overcome, and then the liquid filth may pass into the well with its dangerous ingredients unchanged or unpurified. Nitrates and nitrites are not present in raw sewage, but they are found in polluted streams and watercourses, where a certain amount of oxidation is always in progress, and in the effluent subsoil waters from manured or sewaged land.

Ammonia.—The urea of the urine, by a process of fermentative decomposition, rapidly becomes carbonate of ammonia in sewage. Ammonia will therefore be found in all sewage-polluted waters, unless the sewage has been filtered through a sufficient thickness of soil to enable the bacteria to convert the ammonia by oxidation into nitrates and nitrites. A few pure deep-well waters from the chalk and greensand are found to contain excess of ammonia; but they are remarkably free from organic matters. On the other hand, sewage-polluted shallow-well waters, which contain excess of ammonia, contain also an excessive amount of organic matters.

Organic matters derived from an animal source are dangerous as well as disgusting; the slightest trace of such matters in a water should suffice to condemn it. Organic matters derived from the vegetable world, though often quite harmless, as when they exist in the form of peat, should not be disregarded; and their presence

in considerable quantity should insure the rejection of the water for drinking purposes.

The distinction between animal and vegetable organic matters in a water is often only made with difficulty, if at all. Generally it may be said that, when excess of organic matter in a water co-exists with excessive total solids, chlorine, oxidized N, and ammonia, the source of pollution is animal filth or sewage. When, on the other hand, excessive organic matter is not accompanied by excessive total solids, chlorine, oxidized N, and ammonia, the source of pollution is probably vegetable; and this diagnosis may be confirmed by the results of physical examination of the water, and by microscopic examination of the suspended matters and sediment.

Biological Examination.

Inasmuch as the chemical methods of analysis can only determine the presence and amount of organic matters in water, and cannot determine their quality, nor separate living and possibly actively dangerous organisms from dead and inactive matter, it has been thought by many that methods of cultivating fungi and bacteria on sterilized nutrient media, which was first introduced by Koch, would afford valuable evidence of the possibly dangerous qualities of a water, and might come in time to supersede chemical analysis altogether.

So far such has not been found to be the case, but it is certainly true that a biological examination may throw light on the potable quality of a water which is not to be obtained by chemical methods. The characteristic micro-organisms of cholera and typhoid fever are with difficulty isolated and separated from the crowds of harmless species, which are found in greater or less abundance in all natural waters. The finding, however,

of a greater or less number of non-pathogenic bacteria or fungi in a water simply gives confirmatory evidence of the presence of a larger or smaller amount of organic matter, ammonia, nitrates, or phosphates in the water, which form a suitable pabulum for bacteria.

Chemically pure waters are found to contain very few bacteria or fungi, whilst impure waters often swarm with them. They increase in numbers if water is stored for any length of time.

In addition to a chemical and biological examination of a water sample, it is of great advantage to possess the fullest information as to the risks of pollution which the water has run, and this can only be obtained from a painstaking local investigation.

ANALYTICAL RESULTS OF CERTAIN WATERS (PARTS PER 100,000).

	New River Company (Filtered).	Polluted Well Water.	Peaty Surface Water.	Spring Water from Chalk.	Rain Water.	A Suspicious Water.
Total solids ..	31·2	60·0	10·0	33·0	3·0	40·0
(*a*) Volatile ..	9·8	25·0	7·0	10·0	1·5	15·0
(*b*) Non-volatile	21·4	35·0	3·0	23·0	1·5	25·0
Total hardness ..	21·5	30·0	5·0	26·0	0·75	25·0
(*a*) Temporary	13·0	15·0	1·0	20·0	0·00	14·5
(*b*) Permanent	8·5	15·0	4·0	6·0	0·75	10·5
Chlorine	1·8	8·0	0·7	2·5	0·25	4·0
Oxidized nitrogen	0·18	0·80	0·01	0·30	0·01	0·50
Free and saline NH_3	0·001	0·010	0·001	0·001	0·001	0·006
Organic NH_3 ..	0·003	0·015	0·018	0·003	0·000	0·012
Oxygen absorbed in two hours at 80° F.	0·030	0·160	0·200	0·030	0·015	0·120

CHAPTER II.

THE COLLECTION, REMOVAL, AND DISPOSAL OF EXCRETAL AND OTHER REFUSE.

In any community of persons, arrangements must be made for the collection and removal of their excretal refuse (fæces and urine), of the waste waters from houses, and of the dry refuse (ashes, dust, and refuse food). The solid and liquid refuse matters from stables, cowsheds, and slaughter-houses, street sweepings, and the waste waters from works and manufactories, must also be removed.

In all towns the collection and removal of dung, ashes, dust, refuse food, and street sweepings, is performed by mechanical labour, the various processes above mentioned being included in the term *scavenging;* whilst in some, human fæces and a certain amount of urine are also removed by this method, after being deposited in privies, cesspools, or dry closets, on what is known as the *conservancy system.* In a large majority of the towns of this country, at the present time, human excrement is removed with the liquid refuse of dwellings on what is known as the *water carriage system*—a system of drains and sewers for the passage of the refuse in a liquid condition to some spot outside the town.

On the efficiency with which refuse matters, and especially human excretal refuse, are removed from towns, their health largely depends. The health of towns in this country and abroad has very much improved, and the death rates have been permanently lowered, since the completion of works of sewerage.

Removal of Domestic Dry Refuse.

Household dust, ashes and cinders from fires, scraps of waste food, and other refuse matters, must be stored on the premises of the house until they can be removed by the sanitary authority or by the dust contractor. The dry refuse, therefore, consists partly of mineral matters, but to a considerable extent of organic substances derived from the waste scraps of food. These latter, being prone to undergo decomposition when stored in dust-bins or other receptacles, are very liable to become a source of nuisance. It is, therefore, very desirable that the quantity of organic refuse to be stored on the house premises should be reduced as far as possible; and this may be accomplished by burning the more easily destructible matters, such as potato peelings and other food scraps, in the kitchen fire at the end of every day.

The old-fashioned brick dust-bin is now being largely replaced by galvanized iron pails or boxes, with well-fitting metallic covers, to insure dryness of the contents and their protection from rain. This is an important point, as the presence of moisture hastens putrefaction and the formation of offensive gases in the refuse. The non-absorbent walls of iron pails, and the ease with which they can be moved and carried out to the dust-carts, constitute very great advantages over the brick dust-bins, whose walls become saturated with decaying

matters, and whose contents have to be shovelled out, and are often incompletely removed, at each visit of the scavengers. The contents of the dust-bins or pails should be removed at least twice a week; in summer a more frequent removal is desirable, but is not usually practicable. Specially constructed carts provided with covers should be employed to convey dust refuse through the streets. Horse manure must also be frequently removed from stables, and the removal in urban districts is often attended with considerable nuisance. The nuisance mainly arises at the time of loading the cart in which the manure is removed from the receptacle, the disturbance of the contents of the receptacle giving rise to very offensive gases; and the recently disturbed manure is often highly offensive, as it is carted along public thoroughfares. It is found in practice that the best remedy for the nuisance is to store the manure in the same cart in which it is to be removed.

The disposal of house refuse has hitherto been mainly effected by depositing it on waste ground, the site being commonly called "a shoot." The practice cannot be defended, and it is slowly giving way to a more sanitary method, *i.e.*, the destruction of refuse by fire. As the area of a town increases, these muck-heaps often become the sites for buildings long before natural agencies have succeeded in purifying the "made-soil"; and, moreover, the difficulty of acquiring sites sufficiently near the area to be scavenged is growing greater year by year in our larger towns, and makes the adoption of some other method of house-refuse disposal imperative.

The refuse, when deposited at the "shoot," is often submitted to the process of hand-sorting. The paper and rags are removed for paper-making, the tins and iron for scrap, the bones for manure, the unbroken bottles for

re-use, and the broken glass for re-melting. This sorting process is a degrading occupation; the workers are of necessity in a filthy condition, and the air they breathe is constantly polluted with fine dust and foul odours.

The best method of getting rid of dust-bin refuse is to burn it in a destructor furnace. The proportion of cinders in the refuse is always sufficient to insure complete combustion in a well-constructed furnace. A commercial value attaches to the residuum, either as mortar or screened clinker; and the temperature attained in the furnace, while destroying the refuse, can be utilized to generate steam for electric power, to pump water or sewage, or to drive mortar mills.

There are various types of refuse destructors, most of which possess the following features in common:—The furnaces or cells are strongly built of brick with fire-brick lining, and the general building is also of brick. The destructor is approached by an inclined roadway to the top or tipping platform, which is from 11 to 18 feet above the ground-level. In the centre of this platform is a series of feeding-holes or hoppers into which the refuse is shot, and allowed to fall into the cells below. The stokers rake the refuse forward on to the fire-bars; and after burning, the refuse is reduced to about one-third or one fourth of its original weight, the residue consisting of fine ash, hard clinker, etc. By means of forced draught produced by a steam-jet or blowers, the combustion can be made so complete that temperatures of 1,500 to 2,000° F. are attainable merely from the burning of the refuse.

Some destructors are known as "slow combustion" or "low temperature" destructors, and in these "fume cremators" should be provided at the foot of the chimney. In the fume cremator, which is a coke

furnace, incompletely burned vapours and fine dust particles, which are liable to escape into the air from the destructor furnace, are completely burned up before they can enter the chimney-flue. In the "high temperature" destructors such cremators are unnecessary, and the expense of burning the coke or coke breeze is saved.

The advantages of the "low temperature" destructors consist in the diminished wear and tear on the fire-brick sides of the cells, and the consequent saving in up-keep. On the other hand, the disadvantages are that both the inlet for refuse and the outlet for gases are, as a rule, at the rear of the cell, and therefore the empyreumatic and noxious vapours and fumes given off during the drying of the refuse, and before it is in active combustion, escape before being burnt, and a cremator is necessary. Further, more cells are required, because a smaller quantity of refuse per cell (from 6 to 8 tons) is burnt per day than with "high temperature" destructors. In the "high temperature" destructors (such as the Horsfall or the Beaman and Deas) the outlet for gases is at the front of the cell, and the vapours given off during the process of burning and drying pass over the hottest part of the fire to reach the exit. As the cell is raised to a very high temperature by forced draught (steam blast or fans), such gases are destroyed within the cell itself; a larger quantity of refuse is burnt per day per cell (*i.e.*, from 10 to 16 tons), and fewer cells are therefore required. On the other hand, they cost more for maintenance.

The site on which the destructor is placed should be a central one for the district it is to serve, or the cost for cartage may considerably exceed that for burning; and in some cases it would appear advisable to construct two destructors in different parts of a large town.

The number of cells required will of course depend on

the nature and amount of the refuse to be destroyed, and also upon the type of cell adopted. If a "high temperature" destructor is selected, about ten cells are necessary for a population of 100,000. These cells can be erected in a single row or "back to back." The cost of erection may be taken as about £500 per cell, including enclosing building; and the burning will cost from 9d. to 2s. 6d. per ton, according to the greater or less completeness of combustion required, and the number of tons to be burnt per cell per day.

Human Excreta.

An adult male, living on a mixed diet of animal and vegetable food, passes daily 4 ounces, by weight, of solid, and 50 fluid ounces of liquid excreta. The solid excreta of women and of children under twelve years of age are in amount considerably less, probably, on an average, not much more than one-half the above quantities. If all ages and both sexes are considered, the daily amount of excreta per head of a mixed population may be taken at $2\frac{1}{2}$ ounces of fæces, and 40 fluid ounces of urine. Fresh fæces contain on the average 23·4 per cent. of dry solids, and fresh urine contains 4·2 per cent. (of which 54 per cent. is urea).

To find the amount of dry solid manure produced daily by a population of 10,000, where the pail system is in force, and all the fæces, but only one-third of the *urine*, are *collected* in the pails.

$$\left(10{,}000 \times 2\cdot5 \times \frac{23\cdot4}{100}\right) = 5850 \text{ oz. of dry solids in fæces.}$$

$$\left(10{,}000 \times \frac{1}{3} \times 40 \times \frac{4\cdot2}{100}\right) = 5600 \text{ oz. of dry solids in urine.}$$

$$5850 + 5600 = 11{,}450 \text{ oz.} = \frac{11{,}450}{16}(= 715\cdot6) \text{ lb.} = \frac{715\cdot6}{2240}(=0\cdot32) \text{ ton.}$$

If this manure, instead of being dry, contains 25 per cent. of moisture, it will weigh $\frac{4}{3}$ of $0\cdot32 = 0\cdot43$ ton.

If it contains 50 per cent. of moisture, it will weigh $2 \times 0{\cdot}32 = 0{\cdot}64$ ton.

If it contains 75 per cent. of moisture, it will weigh $4 \times 0{\cdot}32 = 1{\cdot}28$ tons.

And if it contains 90 per cent. of moisture, it will weigh $10 \times 0{\cdot}32 = 3{\cdot}2$ tons.

The quantity of nitrogen voided per head daily in the excreta of a mixed population was calculated by the late Professor Parkes as being 153 grains, or equal to 186 grains of ammonia. The other valuable constituents of the excreta are phosphates and potash. A given weight of fæces is more valuable than the same weight of urine, in the proportion of about ten to six; but the weight of urine passed daily (in a mixed population) is about sixteen times as great as that of the fæces, consequently the total urine is worth about ten times as much as the total fæces.

The estimated or theoretical money value, then, of the excretal refuse of an individual of a mixed population for one year may be taken as being 6s. 8d. to 7s. It is very evident that it must be impossible to realize practically any such value, because it is impossible to collect the whole of the urine and fæces free from admixture with other substances, which greatly detract from the value because they are agriculturally worthless.

Fæces and urine, especially when mixed, as in cess-pools, privies, and sewers, rapidly undergo putrefactive changes, giving rise to the formation of fœtid gases (organic vapours, ammonium sulphide, etc.). The urea —$CO(NH_2)_2$—of the urine decomposes, giving rise to carbonate of ammonia—$CO(NH_2)_2 + 2H_2O = (NH_4)_2CO_3$ —and so rapid is this change that it is probable that, even in the best-sewered town, all the urea of the urine in the sewage has been converted into ammonia before the arrival of the sewage at the outfall.

House Waste Waters.

In these are included the waste waters from kitchens, which are highly charged with decomposable organic matters and grease, and slop waters containing urine, soap, and the dirt from the surface of the body and from clothes. These waste waters, when mixed with the liquid refuse or drainage of stables, cowsheds, and slaughter-houses, with the washings from the street surfaces, with the urine from public urinals, and the waste liquors from manufactories, form the sewage of the non-water-closeted or midden towns. The drainage from stables is very rich in urine (one horse excretes about fifteen times as much urine as an adult man), and the waste liquors from manufactories are often excessively foul.

It is not surprising, then, to find that such sewage is often quite as foul as that of water-closeted towns, which contains the solid human excreta as well. The putrescible organic matters in suspension are greater in midden than in water-closet sewage, whilst the organic matters in solution are but slightly less in the former than in the latter. The Rivers Pollution Commissioners stated in their First Report that, " for agricultural purposes, 10 tons of average water-closet sewage may, in round numbers, be taken to be equal to 12 tons of average privy sewage"—*i.e.*, sewage of privy towns, where human fæcal matters are kept out of the sewers. Such being the case, it is necessary to bear in mind that, in towns where there are middens or some form of dry closet for the collection of fæcal matters, there is also a liquid sewage to be conveyed away from houses by drains and from the town by sewers, which is too impure to be admitted into a stream, and which must therefore be purified before being discharged.

Conservancy Systems.

The Privy or Midden System.—The system which formerly prevailed in many towns in this country—where there was any system at all—was that of privies, midden pits, and cesspools, often open to the air and unprotected from rain, and situated in the yards and areas about houses. These receptacles were generally mere holes dug in the ground, and their contents overflowed, saturating the air with noxious effluvia, or percolated into the soil around the houses, and poisoned the water in the neighbouring wells.

At the present time, in those towns which still retain conservancy systems, the middens are required to be constructed according to certain definite rules. The model bye-laws of the Local Government Board with regard to the construction of privies and middens for new buildings require that the privy must be at least 6 feet away from any dwelling, and 40 or 50 feet away from any well, spring, or stream; means of access must be provided for the scavenger, so that the filth need not be carried through a dwelling; the privy must be roofed to keep out rain, and provided with ventilating openings as near the top as practicable; that part of the floor of the privy which is not under the seat must be not less than 6 inches above the level of the adjoining ground, must be flagged or paved with hard tiles, and must have an inclination towards the door of the privy of ½ inch to the foot; the capacity of the receptacle under the seat of the privy must not exceed 8 cubic feet—a weekly removal is then necessary; the floor of this receptacle must be in every part at least 3 inches above the level of the adjoining ground; the sides and floor of this receptacle must be constructed of impermeable material

—they may be flagged or asphalted, or constructed of 9-inch brickwork rendered in cement; the seat may be hinged, or other means of access to the contents of the privy must be provided; and the receptacle must not communicate with any drain or sewer.

With privies constructed and managed according to these rules, there would be no danger of percolation of liquid filth into the soil around houses and in the neighbourhood of wells; and there would not be much pollution of the air from the excreta—except during removal—if dryness was insured by the proper application to them of ashes and cinders. The success of the system depends to a large extent on efficient inspection by the sanitary inspector, and on proper scavenging arrangements.

Cesspools.—These receptacles for filth are so evidently undesirable in the neighbourhood of houses that it is the practice now in nearly all towns to fill them in, and provide more suitable means for the collection of excreta. Until the repeal, in 1815, of the law which prohibited the passage of sewage from houses into the sewers, nearly every large house in a town had a cesspool on the premises, often of enormous size and situated in the basement. When, in the year 1847, it became compulsory to carry house drains into sewers, many of these cesspools were filled up or otherwise abolished; but many of them escaped observation, and to the present day it is no unusual thing to find one or more cesspools in the basements of town houses, of the existence of which the owners or occupiers are ignorant.

In country districts where there are no sewers, cesspools are still largely used for the reception of human excreta and waste waters. When dug in a porous soil, such as gravel or chalk, they are too frequently con-

structed to allow all the liquid filth to percolate through their walls into the soil, with the almost certain danger of polluting wells, springs, and other sources of underground water-supply. When the liquids escape thus easily, the cesspool but very rarely requires emptying, and this fact constitutes the *raison d'être* of the porous cesspool.

The model bye-laws of the Local Government Board for new buildings require that a cesspool must be at least 50 feet away from a dwelling, and 60 to 80 feet distant from a well, spring, or stream. It must have no communication with a drain or sewer (in sewered districts); its walls and floor must be constructed of good brickwork in cement, rendered inside with cement, and with a backing of at least 9 inches of well-puddled clay around and beneath the brickwork. The top of the cesspool must be arched over, and means of ventilation provided. Constructed in accordance with these rules, the possible dangers of cesspools are reduced to a minimum.

In this country cesspools are generally emptied by hand labour—a disgusting and dangerous task—or by pumping into a night-soil cart. On the Continent, and especially in Paris—where nearly every house has its *fosse permanente* in the courtyard—the cesspools are emptied by pneumatic pressure. A flexible tube, connected with a tub or *tonneau* exhausted of air by an air-pump, is thrust down to the bottom of the cesspool. On turning a valve, the pressure of the atmosphere forces the contents up into the *tonneau*. This method is said not to give rise to any nuisance comparable with that from emptying the cesspools by hand labour. Whenever a cesspool or privy-pit ceases to be used, it should be completely emptied, and the contaminated

brickwork, earth, etc., removed; or, after emptying, its walls should be well limed, and then filled up to the ground-level with good concrete or with suitable dry, clean earth or brick rubbish.

The Pail System.—In this system the excreta are received into movable receptacles, such as pails and tubs. Removal is thereby greatly facilitated, and there is no pollution of the air from disturbance of contents, as there always must be when the contents of middens are taken away. In some towns iron pails are used, in others tarred oak pails. The capacity of the pail should not be greater than 2 cubic feet. Both kinds should be provided with a close-fitting lid, to be adjusted before removal of the pail by the scavenger.

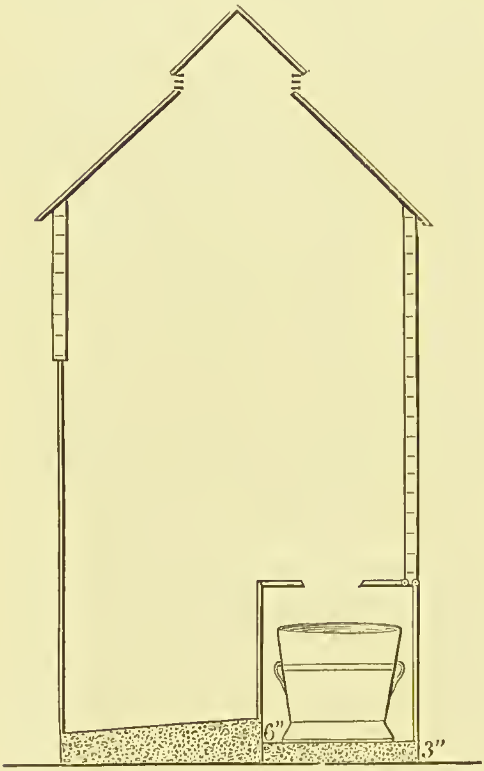


FIG. 5.—PRIVY CONSTRUCTED FOR PAIL SYSTEM.

The structure of the privy (Fig. 5) need only be very simple; it should be well roofed and louvred for ventilation, its floor being raised above the level of the ground adjoining and flagged, and the pail placed under the seat. The seat may be hinged, to insure a more

complete covering of the excreta with cinders and ashes, when these are used, and to allow of the removal of the pail; or the back wall of the closet may be provided with a door to effect the latter purpose. The pail should be removed at not longer intervals than once a week, and a clean one substituted.

It is very important, from a sanitary point of view, that the pail contents should be kept as dry as possible; and for this object the house ashes and cinders should be thrown into the pail, either by a scoop after each use of the closet, or by a mechanical arrangement (to be described under earth-closets) above the pail, which sifts the cinders and deposits the fine ash automatically on the pail contents, as in Morell's closet. At Nottingham the pails are the receptacles for the chamber urine and solid kitchen refuse, as well as for the excreta and ashes. It is perhaps convenient for the authorities to remove all house refuse in one receptacle; but if it is intended to create a saleable manure from the excretal refuse, all garbage and kitchen refuse, and even all but the very finest ash (for this detracts from the value of the manure), should be kept out of the pails and removed separately. In such cases the pail contents can no longer be kept dry, and sanitary considerations are, to a certain extent, sacrificed to insure commercial ends.

All slops should be kept out of the pails, and should be carried away from the houses in drains, with the other waste waters. In some cases separation of the urine from the fæces has been attempted. Besides introducing a complication into a system whose chief merit, perhaps, is simplicity, this plan is open to the great objection of abstracting the most valuable fertilizing constituents of the manure *in posse*.

In the *Goux system* an attempt is made to dry the

excreta by lining a wooden tub with a layer of refuse sawdust, shoddy, tan, or other absorbent material, to which is added a little soot, charcoal, gypsum, or other cheap deodorizer. This system is in use at Halifax, and on the whole has worked well.

Wood charcoal and charcoal obtained from seaweed (Stanford's patent) have been used instead of ashes to aid in drying the pail contents. They act as absorbents, and possibly to a certain extent as deodorizers.

Manufacture of Manure.—In towns situated in agricultural districts, where there is a demand for the coarser sorts of manure, the pail contents need merely be mixed with a certain portion of fine ash. But in some of the large towns, where the pail systems are in vogue, it is now the practice to convert the pail contents into a dry manure of a more imperishable character, which can be packed and sold at a distance. The heat required for this purpose is generated by the combustion of house cinders and refuse in a destructor furnace, the invention of Mr. Fryer.

The pail contents—urine and fæces without ashes—are mixed with a small portion of sulphuric acid, to fix the ammonia, in an air-tight store tank, where the thicker portion of the material settles at the bottom. The more fluid portion of the contents of the tank is drawn off into evaporators, which are tall cast-iron cylinders, each containing near its lower end a drum-shaped heater, precisely resembling a multitubular steam-boiler. These cylinders are partially filled, and the heating drums are covered with the thin liquid; steam is then introduced within the heating drums, and the liquid becomes partially concentrated.

When the contents of these cylinders have lost by evaporation the greater portion of their water, they are

drawn off into a Firman's Dryer, into which the thick portion of the pail contents, which settled in the store tank, has also been admitted. This machine consists of a steam-jacketed horizontal cylinder, traversed by a steam-heated axis with steam-heated revolving arms, and furnished with scrapers to keep the inner surface of the cylinder free from accumulations of dried excreta. The pail contents are admitted into the dryer at a consistency of thin mud; after treatment they emerge as a dry powder—*poudrette*—resembling guano in appearance and quality, and estimated to be worth from £3 to £6 per ton, dependent upon analysis. The odorous gases given off during the process are all passed through the destructor fire and burnt. From the time the liquid material enters the store tank until the end of the process when it emerges as a dry powder, no odorous gases should escape into the outer air, and no nuisance ought to result.

The Dry Earth System.—This system is the invention of the late Rev. Henry Moule, and consists in the application to the excreta, deposited in a pail or tub, of a certain quantity of dried and sifted earth. One and a half pounds of dry earth applied in *detail*, *i.e.*, each particular stool being covered at once with this quantity, is found to be sufficient to remove all smell and to form a compost which remains inoffensive as long as it is dry. A certain action takes place in the mixture of earth and excrement, which results in the complete disintegration of the fæcal matters and paper, which after a time are found to have completely disappeared and are no longer recognisable. The compost after further drying may be used over again, and has the same action as the original dry earth. The best kinds of earth are brick earth, loamy surface soils, and vegetable mould. Sand, gravel, and chalk are unsuitable and inefficient.

The closet generally used with this system is almost identical with the cinder-sifting ash-closet, previously mentioned. There is a hopper or metallic receptacle above and behind the seat, and the proper amount of dry earth is shot into the pail by a simple mechanical contrivance connected with a handle, or self-acting seat arrangement. The contents of the pail must be kept as dry as possible, or fermentation results, with the disengagement of foul gases; consequently slops must on no account be thrown into them, and even chamber urine must be kept out of them, unless a considerable extra quantity of dry earth is used. The earth must be dried, before use, over a stove, and then sifted by means of a sieve, the finer portions only being used.

There can be but little doubt that the compost or manure produced by the passage of the earth even five or six times through the closet has but little agricultural value. The late Dr. Voelcker estimated its value as only 7s. 6d. per ton. It is probable that there is some escape or evolution of nitrogen in a free state from the manure when kept; and this may partly account for its deficiency in fertilizing properties. But when we reflect on the large amount of valueless earth with which the compost is diluted, and the absence from it of a large proportion of the daily urine of each individual, the reasons for its low value are not far to seek.

The Disposal of Slop Waters.

We have already seen that the conservancy systems do not provide for the removal of the liquid refuse, domestic or municipal; and we have seen, too, that in the so-called midden towns this liquid refuse or sewage is quite as impure as the ordinary sewage of water-closet

towns. In these towns, too, there is always a certain percentage of houses provided with water-closets, so that the crude matter passing into the sewers is inadmissible into a river or stream, and requires to be purified. A system of drains and sewers is necessary for its removal from the town; and the principles on which such drains and sewers must be constructed do not differ from those which would be necessary if they were intended to carry water-closet sewage as well.

In small villages and isolated houses, provided with middens or some form of dry closet, the slop waters are usually carried by a drain from a sink or yard gully into "sumpt" holes in the garden, into an open ditch, into a cesspool, or into a stream: if into a "sumpt" hole or open ditch, there to stagnate and generate offensive gases; if into a cesspool, often to percolate through its porous walls and pollute the neighbouring wells; and if into a stream, to foul it nearly as much as if they contained the solid excreta also. The slop waters may be retained in cesspools which are rendered impermeable by brickwork set in cement and well puddled with clay outside; and they can then be utilized on garden ground by means of a pump and hose and jet. They may also be passed through a small coke or ash filter, which should be prepared on a specially selected area well away from the house; or they may be disposed of by irrigation upon grass fields. Wherever the nature of the soil—a porous soil is best—and the slope of the land will permit of it, recourse may be had to *sub-irrigation*, to purify the dirty water and utilize it to the best advantage. A very small piece of ground is required for this purpose. Mr. Rogers Field considered 4 perches of land sufficient for an ordinary cottage. The drain conveying the slop waters from the house should be connected by a few lengths of imperme-

able piping with a system of 2-inch agricultural porous earthenware pipes, laid about 5 or 6 feet apart, with open joints, at a depth of about 8 to 12 inches in the soil, the whole having a slight fall or inclination away from the house of 6 or 8 inches in 100 feet. The ends of the pipes should rest upon cradles formed of half-pipes, and similar covers should be placed above, so as to prevent earth getting into the pipes, whilst allowing the water to escape. The lower end of the main outlet pipe should turn up into the air to allow air to escape. This is especially necessary when the slop waters are discharged into the sub-irrigation drains by a flush tank.

If the soil is very porous, no under-drainage is needed; otherwise, porous drain pipes must be laid at a depth of about 3 feet from the surface, with an outlet into a stream or ditch. The slop waters escape through the open joints of the sub-irrigation pipes into the soil, where some of their fertilizing ingredients are absorbed by the roots of the grasses and vegetables grown on the plot, and the rest is purified by percolation through the soil; so that the effluent water passes away free from all polluting organic matters into a stream or ditch, or helps to swell the volume of the subsoil water.

The chief difficulty in connection with this method is that the flow of slop waters from a single house is so small that the liquid penetrates but a short way along the sub-irrigation pipes, which become in time choked with deposit; and that portion of the sub-irrigation plot nearest the house receives an unduly large share of the irrigating liquid, and its cleansing properties are speedily overtaxed. This difficulty has been overcome by providing a flush tank which will discharge at intervals into the head of the system. The tank now in most general

use for this purpose is fitted with the annular siphon arrangement invented by Mr. Rogers Field.

In the annular siphon (Fig. 6) the ascending arm of an ordinary siphon is represented by a short wide cylindrical pipe, closed at the top, which is placed over and encloses the descending arm, a longer pipe of smaller diameter. The upper end of the descending arm is open, and in Field's tank is provided with a lip projecting inwards and downwards, which serves to direct the water, as it overflows, into the centre of the pipe. The lower end of the descending arm opens over a discharging trough below the body of the tank, and is trapped by the water which stands in this trough to the level of the top of a weir, over which the water flows into a pipe connected with the head of the sub-irrigation system.

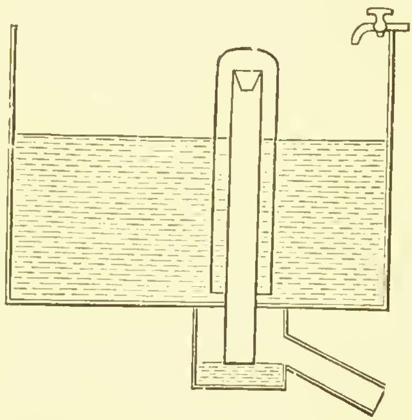


FIG. 6.—FIELD'S ANNULAR SIPHON FLUSH TANK.

Only a very small dribble of water into the tank is necessary to put the siphon into action. This takes place as follows: As the cistern fills the water ascends between the inner and outer pipes constituting the siphon, until it reaches the level of the top of the inner pipe, the air displaced finding an exit through this pipe and the discharging trough below. The water then trickles over the top of the inner pipe, and, thrown into its centre by the lip, falls clear of the sides, entangling and carrying air with it, which cannot pass back, owing to the lower end of the pipe being trapped. This con-

tinues until the siphon is sufficiently exhausted of air to be brought into action, when the whole contents are discharged by siphonage.

The frequency of discharge of the tank can be regulated by adjusting the tap through which the water enters; the merest dribble is usually quite sufficient. This tank in practice works admirably, "dribbling" and "continuous action" being impossible, if it is placed on a perfectly level surface with the discharge pipe quite plumb. Flush tanks are now usually fitted with a "reversed" ball-valve. When the ball is depressed in the tank very little water passes through the valve; but when the tank is very nearly full the valve is fully opened, a rush of water enters the tank, and siphonage at once takes place. Dribbling and continuous action, which are due to the smallness of flow into the tank, are thus avoided, whilst the time of filling the tank can still be regulated as desired.

It is not necessary to strain the slop waters before they enter the tank, as they contain but few of the coarser suspended matters and solid particles found in water-closet sewage. The sub-irrigation drains require to be taken out of the ground, and the deposit removed before they are relaid, about once every five years, according to circumstances.

Comparison of Methods.

There can be no doubt that all conservancy systems proceed on a wrong principle, viz., that of keeping excremental matters within or near dwellings as long as they are not considered to be a nuisance or a danger to health. In towns the expense of scavenging is directly proportional to the frequency of removal, so that there is always an inducement to the local authority to economize at the risk of the health of the inhabitants. The costs of this

kind of scavenging are high—in many towns very high—and in but very few does the sale of the refuse cover the expense. That improved middens and pail or earth closets are a great advance upon the former disgraceful conditions which prevailed in most towns, nobody will deny. The principal objection to them is that they only deal with a small part of the refuse of a population, and fail to deal with the sewage of a highly polluting character.

Movable receptacles are far better than fixed ones for the collection of excremental matters. By the use of pails, the pollution of the air caused by the removal of the contents of the middens, and the pollution of the soil—always a danger with middens—are avoided. Ashes or dry earth should be used with the pails to insure, as far as possible, dryness of their contents. It is better to sacrifice a possible profit on the manure than to run the risk of spreading disease by fermentation of the liquid filth. The pail system is undoubtedly the best for towns which will not enforce the adoption of water-closets. But, however suitable for country houses and villages in this country, and for villages and stations in India, and in cold countries, where the water-supply is small and liable to interruptions, and where earth of suitable quality is easily procured and dried, and the compost can be distributed over gardens and fields in the immediate vicinity, it is quite inapplicable to towns of any size, on account of the enormous quantities of earth that would have to be dried and brought into the town, the difficulties of storing the earth on the premises of houses and keeping it dry, and the still larger quantity of nearly worthless manure to be removed out of the town and finally disposed of.

The Water-Carriage System.

In this system the solid excreta together with all liquid refuse are conveyed away—borne along by flowing water—in drains and sewers from the neighbourhood of houses and towns. In many towns, before any general introduction of water-closets, sewers existed for conveying away house waste waters, stable drainage, surface and storm waters, and in some cases waste liquors from manufactories. These sewers, which were made of brick, oval or circular in section, acted also as land drains; for not being constructed of impermeable materials, they admitted subsoil water, and had considerable effect in drying the soil.

It became at one time also the practice to drain off the liquid contents of privies and middens, or to carry overflow pipes from cesspools into these sewers, which, not being designed to receive excremental refuse of this description, speedily became choked with sediment. This sediment rapidly putrefied, and the offensive gases given off created an abominable nuisance. It then became necessary for the sewers to be regularly cleansed, and this deposit had to be removed at great expense by hand labour. The drainage of privies and middens entered the sewers in a most foul and offensive condition, owing to the putrid state of the contents of these receptacles. Another result was that the streams and rivers into which this sewage was permitted to pass became highly polluted. In many towns these brick sewers still exist, and perform the double function of removing sewage and rain water, and draining the subsoil; whilst in others they are only permitted to perform their original function of carrying off rain and surface water and of draining the subsoil, impermeable pipe

sewers being laid to remove the sewage of the town on what is known as the *separate system*.

House Drainage Arrangements.

Water-closets.—A water-closet may be defined as an apparatus for the reception of excrement, which is connected with a sewer by a pipe, and in which water must be used to carry away the excrement deposited in it. It is therefore seen at once to differ in all essentials from a privy, which ought not to be connected in any way with a sewer, and in which water cannot properly be used. Water-closets may be classified under two heads: (*a*) Those in which there is no movable apparatus for retaining water in the basin; (*b*) those in which there is such a movable apparatus. Under the first head are included the various types of *hopper closets;* under the second head, *pan*, *valve*, and *plug closets*.

The *hopper closet* consists of an inverted stoneware cone, connected below with an ⊔⊓-shaped pipe, which retains sufficient water to prevent the free passage of air, and is known as a *siphon trap.* The old form of hopper closet called the *long hopper*, from the length of the cone (Fig. 7), is liable to fouling of the basin, and is difficult to flush, especially where the water is admitted by a side-inlet which has the effect of causing the water to whirl round and round, whereby the trap is not flushed out and excreta are left behind. The *short hopper* (Fig. 8) is constructed with a shorter cone of china or stoneware; the back of the cone should be made nearly vertical, so that the excrement drops into the water of the trap, and not upon the sides of the basin. The short hopper, especially when constructed with a "flushing rim," by which the sides of the basin are well washed, is found, under proper management, to be easily kept clean. The

closet should be flushed from a waste-preventing cistern holding not less than 2 gallons of water, and placed not less than 4 feet above the seat, the service or supply pipe being

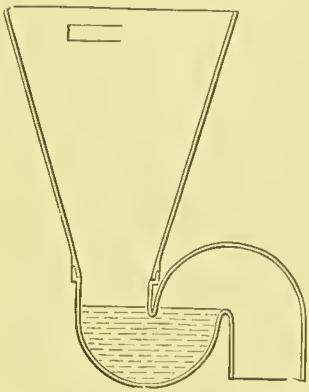


FIG. 7.—LONG HOPPER WATER-CLOSET WITH SIDE-INLET FOR FLUSHING.

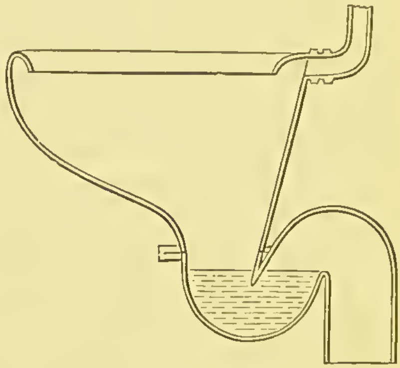


FIG. 8.—SHORT HOPPER WATER-CLOSET.

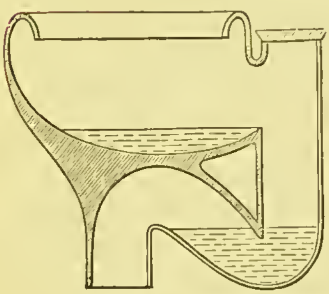


FIG. 9.—WASH-OUT WATER-CLOSET.

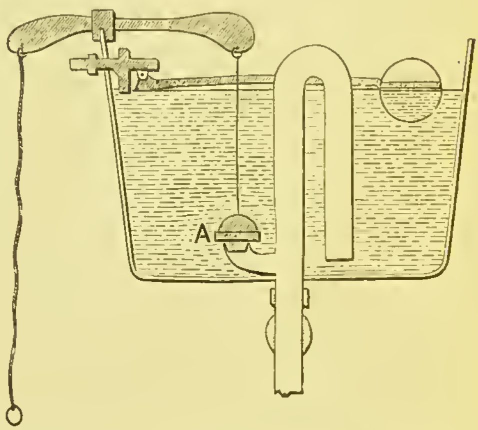


FIG. 10.—SIPHON ACTION WATER-WASTE PREVENTER.

$1\frac{1}{4}$ or $1\frac{1}{2}$ inches in diameter. It is a form of closet which is now largely in use, for it is simple in construction, inexpensive, has no confined air-space where foul air could

accumulate, and conveys slop waters away at once, no overflow pipe being necessary.

For the out-door water-closets of the houses of the working classes the short hopper closet, made in stout glazed stoneware, is far the best. The floor of the closet should not be of wood, but of cement concrete sloped towards the door of the closet. The siphon trap under the closet basin should be fixed upon the cement floor by embedding it in cement so as to form a pedestal, and thus rendering it and the basin very strong and perfectly secure. There should be no vertical wooden casing, and the seat should be hinged, so that every corner around the space beneath this seat can be got at for cleansing. The trap of the closet should be jointed at the back of the basin to a 4-inch stoneware drain pipe by a cemented joint. A closet fixed after this manner will stand a great deal of rough usage without getting broken or out of order.

The *wash-out closet* (Fig. 9) is constructed of stoneware or china, with the basin so shaped that a small quantity of water remains in it to receive the excreta, which are flushed out over the edge of the basin into a siphon trap below. This form of closet is difficult to flush with only 2 gallons of water, for the rush of the water from the flushing cistern is broken by the force necessary to clear out the contents of the basin ; and then the water falls into the trap, but usually without sufficient impetus to propel the excreta through it. The basin, too, is very apt to become soiled by solid matters near the outlet. The basin—as in the case of every closet basin—should be provided with a flushing rim.

Various "siphonic" closets are now made by English manufacturers, in which the contents of the basin are not only forced out by the water-flush, but are also sucked

out by means of a temporarily induced siphonage in the trap. Not all of these closets are reliable, as in some cases it has been found that foul water returns to the basin after flushing; also to prevent the siphon becoming "air-bound" air-escape pipes have to be inserted—an undesirable complication of what should be a simple apparatus.

Water-waste preventing cisterns should be used with each of these three forms of closet, both for economy of water and to break the connection between the house cistern, used for drinking-water, and the water-closet basin. Where there is no house cistern, the water being supplied by constant service, the water-waste preventer is especially necessary. Numerous outbreaks of enteric fever have been traced to the ascent of foul air and liquid filth from water-closet basins up the supply pipes into the water-mains, with which they were directly connected. One of the simplest forms of water-waste preventer merely has a spindle valve in the cistern on the supply pipe to the closet, which can be raised by pulling a chain attached to a lever, when the water—2 or 2½ gallons—is discharged. When the lever is depressed by the chain, the ball valve is raised, and no more water can enter the waste preventer as long as the chain is held. The chain must be held until the waste preventer is empty.

The best form (Fig. 10) of water-waste preventer is that with a siphon action. A very short pull of the chain will put the siphon in action, when the whole contents of the cistern are discharged. No more water can then escape until the cistern is refilled and the chain again pulled, as when the valve is raised a leather plug (A) slips off its lower surface, and closes the orifice to the down-pipe. There are numerous other forms of siphon water-waste preventer. The especial advantage

of the siphon action is that the cistern is emptied by a very short pull of the chain—an important factor in the proper flushing of closets used by careless persons.

These cisterns should be fixed at a height of not less than 4 feet above the closet basin. If this "head" is not obtainable, a good flush can be secured by using a cistern with a comparatively large outlet pipe, which is only narrowed just before it joins the basin.

The closets already described are more especially useful out of doors and in the basements of houses, where they can be directly connected with the drain. The joint between the china or stoneware trap and lead soil pipe is difficult to make perfectly secure. Therefore it is better for these closets, where they must be connected to a lead soil pipe, to have lead traps, as a wiped joint can be easily made between the closet trap and the soil pipe. The disadvantage of the lead trap is that it cannot be enamelled internally, and enamel paints soon wear off, giving a dirty appearance to the bottom of the closet. The joint between the china trap and the lead soil pipe can be made with *marine glue*—a mixture of indiarubber, 1 part, and powdered shellac, 20 parts, dissolved in 12 parts of benzole. This makes a tough and adhesive yet elastic joint. In most cases a good joint is made by wiping a brass collar on to the soil pipe, when the joint between the china trap and brass collar is made with cement, a little asbestos being employed to prevent the cement finding its way into the interior of the pipe; or, again, the lead may be drawn out and bolted upon a flange upon the china trap by means of a cast-iron collar, the joint being made with red lead. More recently a very good joint has been made by coating the end of the china trap with a very thin layer of metallic platinum, which adheres strongly to the china. The lead pipe is

then soldered to the platinum-covered china in the ordinary way, the solder "tinning" well on the platinum.

Under the head of closets with a movable apparatus for retaining water in the basin, we have the pan, the valve, and the plug closets.

The *pan closet* (Fig. 11) has been more largely in use than any other form in the better class of houses; and it is undoubtedly a very badly contrived closet, and one which is most productive of nuisance.

The pan closet consists of a china basin, shaped like an inverted cone, with its outlet guarded by a movable metal pan, which retains water in the basin; and for this purpose the pan must be of considerable size. On raising the handle of the closet, the pan is swung back into a large rounded cast-iron receptacle called the "container," into which the excreta and water fall. From the bottom of the container a short pipe leads to a trap—usually a D trap—designed to prevent the passage of foul air from the soil pipe into the closet. The interior of the container becomes much splashed and soiled by the excreta; and the deposit thus formed putrefies, giving rise to foul gases which escape into the air of the closet apartment as soon as the pan is swung back.

The *D trap*—so called from its resemblance to the letter placed sideways (ᗜ)—is made of lead, and quickly becomes coated with a deposit of foul matter in those parts which are not flushed by the water passing through it. This deposit, like that in the container, gives rise to the formation of foul gases. The walls of old D traps and containers, and the soil pipes with which they are connected, are not uncommonly found perforated in places, owing to the chemical action of the fluids and gases. Pan closets and D traps, wherever

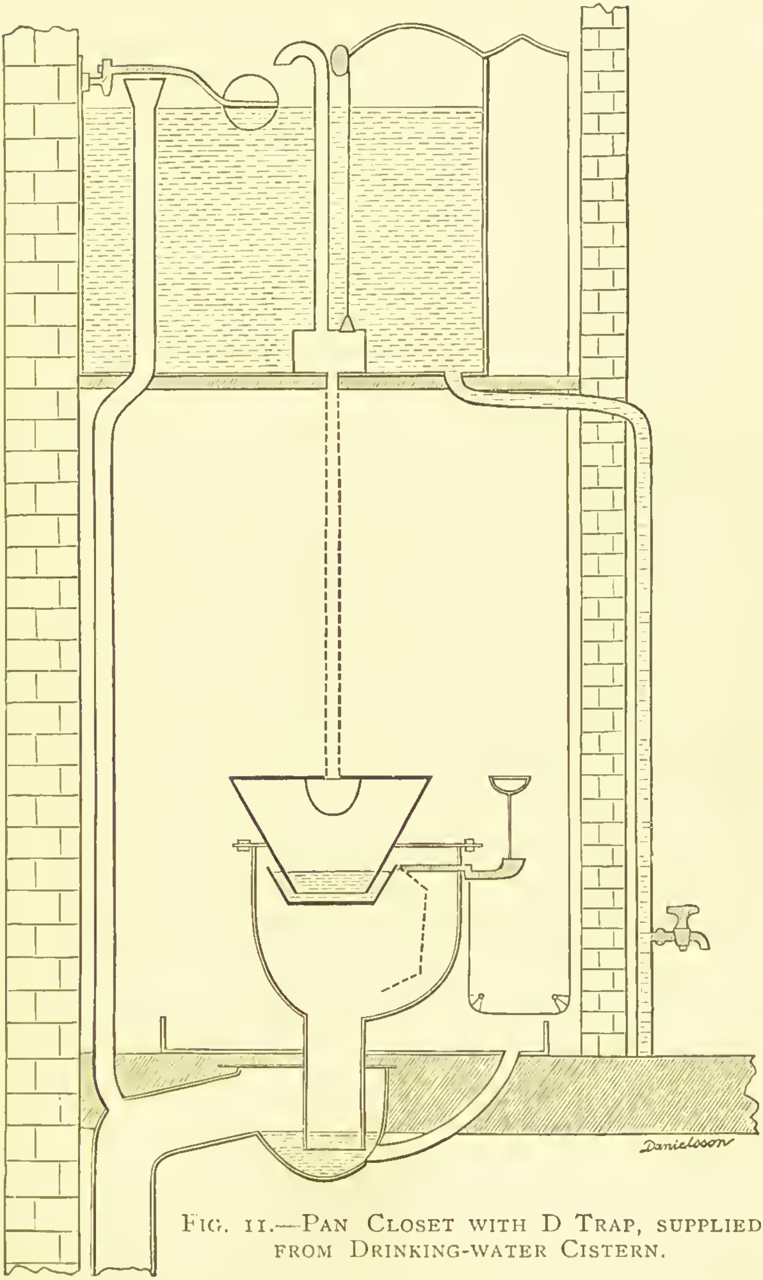


FIG. 11.—PAN CLOSET WITH D TRAP, SUPPLIED FROM DRINKING-WATER CISTERN.

Standing waste pipe directly connected with unventilated soil pipe. Waste pipe of safe tray enters the D trap.

found, should be replaced by one of those forms of closet which are capable of being flushed in such a manner that no deposit of filth can take place in any part of the apparatus.

The *valve closet* (Fig. 12), which is now largely in use, consists of a semi-spherical basin of china or stoneware, with a circular outlet at its lowest part, 3 inches in diameter. This outlet is closed by a circular water-tight valve, hinged at one side where it is connected with the handle of the closet. On raising the handle, the free edge of the valve is depressed into a metal valve box, just large enough to allow the valve to assume a perpendicular position. The valve box is connected at its lower part with a trap—preferably a siphon trap, or an anti-D trap formed of 4-inch lead pipe—and the outlet of this trap is connected with the soil pipe. The valve closet should be flushed from a small cistern holding 6 or 8 gallons of water, and not from a water-waste preventer, as it is necessary to provide a considerable "after-flush"—that is to say, to allow a supply of water to enter the basin after the handle is released and the valve closed.

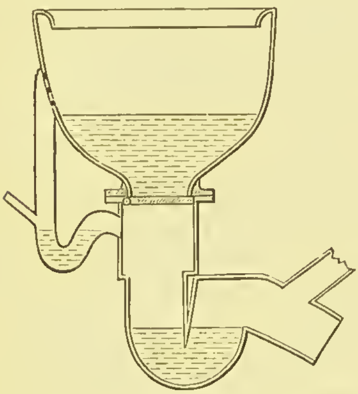


FIG. 12. — VALVE WATER-CLOSET WITH ANTI-D TRAP AND ANTI-SIPHONAGE PIPE.

To secure an after-flush, some form of "regulator" valve in the supply pipe from the cistern to the closet basin must be used. The "bellows regulator," which is commonly used, consists of a piston working in a cylinder, and connected with the handle of the closet

and with the valve in the supply pipe. The cylinder is provided with an escape pipe for air, on which is a tap to regulate the speed with which the piston falls. When the handle is raised, the valve in the supply pipe is opened, and the piston also is raised; but on letting go the handle—the valve to the closet basin being then closed—the valve on the supply pipe is kept open, admitting water to the basin, until the piston has completely fallen and thereby closed it. The amount of after-flush, which is directly proportional to the slowness with which the piston sinks in the cylinder, can be regulated to a great nicety by the tap on the air-escape pipe.

As the outlet to the closet basin is guarded by a water-tight valve, the basin is liable to overflow from too much after-flush, or from the throwing in of slops. It is necessary, therefore, to provide an overflow pipe to the basin; this is usually carried from near the top of the basin into the valve box below, after forming an ∽ bend, which by holding water prevents the ascent of foul air from the valve box. But it is found in practice that foul matters may find their way into or accumulate in the overflow pipe, and that the water in the bend is liable to be drawn out by siphonage, when the contents of the basin are discharged through the valve box.

Two precautions are adopted to obviate this difficulty. The first is to carry the overflow pipe into that side of the valve box where its open end will be protected by the depressed valve; and the second, which is most necessary, is to carry a branch pipe from the supply pipe, near the regulator valve, into the bend, whereby the water in it is renewed at each use of the closet. The basin of the closet should be provided with a flushing rim. Occasionally a ventilating or "puff" pipe is attached to the valve box, and carried up and out into the open air, being left

with an open end away from any windows. When the contents of the basin are being discharged, the foul air in the valve box then escapes into the open air, instead of into the closet compartment.

There is very little risk of the deposition of filth in any part of the apparatus, as the large volume of water which the basin can contain effectually flushes the small valve box and trap beneath. Occasionally the valve box is enamelled inside to prevent corrosion. The chief disadvantage of the closet is that the valve may become in time leaky, allowing the water in the basin to escape, and possibly foul air to ascend into the general air of the closet.

The *anti-D trap* (see Fig. 12) is a ⋃⋂-bent pipe, like the siphon trap, but the calibre of the pipe is diminished in the bent portion which holds the trapping water, and the bend of the pipe beyond the trap, instead of being circular, is squared. These properties cause some resistance to the passage of water through the trap, and tend to prevent both *siphonage by suction—i.e.*, the drawing of the water in the trap by the passage of water down the soil pipe from a higher level—and *siphonage by momentum*, which may occur in plain siphon traps by the water discharged from the water-closet sweeping through the trap, none remaining behind to form the water-seal. The depth of the water-seal in water-closet traps should not be less than 1 inch, and not greater than 1¾ inches. If the depth of the water-seal is too small, there is a liability for the trap to be unsealed; if the seal is too great, the trap and the closet above it are not self-cleansing with an ordinary flush of water. These remarks apply more especially to "wash-down" closets (short hoppers) with water-waste preventers.

In the *plug closet* the basin and trap are usually cast in

one piece of china or stoneware, the basin above being shut off from the trap (siphon) below by a solid plug or plunger, by which water is retained in the basin. The cistern and flushing arrangements may be the same as those for the valve closet, an after-flush being necessary for both alike. The plug, which is connected directly with the handle, is usually perforated by a channel bent on itself so as to form a trap, and thus provides an overflow to the basin, permitting water to pass through the plug to the trap beneath. Sometimes these closets are used without the trap beneath, but in both plug and valve closets a siphon trap is necessary to prevent the passage of foul air from the soil pipe when the closet is discharging its contents. The plug or plunger is liable to become much soiled, and, being out of sight, escapes cleaning. When this is so, it may happen that excretal filth is forced up on to the handle when the plug is suddenly plunged. This constitutes a great disadvantage in use. The valve and plug closets are under the disadvantage of having a space between the water in the basin and the water in the trap, from which air—possibly foul—escapes into the general air of the closet when the contents of the basin are being discharged. But they have this advantage over those of the first class, that the larger quantity of water in the basin renders them more cleanly in use. The "siphonic" closets have been so recently invented that we are unable to speak with certainty as to their practical working. Possibly the best forms of siphonic hopper closets may possess the advantages, without the drawbacks, of both the classes of water-closets we have described.

On the floor beneath the closet basin is usually placed a lead or zinc *safe-tray*, to catch any overflow. This tray should be provided with a waste pipe, which must be

carried through the wall into the outer air, its end being covered by a brass flapper to prevent cold currents of air passing into the house. It was formerly the custom to connect this waste pipe with the D trap (see Fig. 11) under the closet basin, thereby permitting foul air to enter the house at all times.

Water-closets should be placed against the outside wall of a building, in which is a window reaching to the ceiling. Where possible, they should be separated from the house by a well-ventilated lobby; for it is important that air from the closet should find an easy exit to the

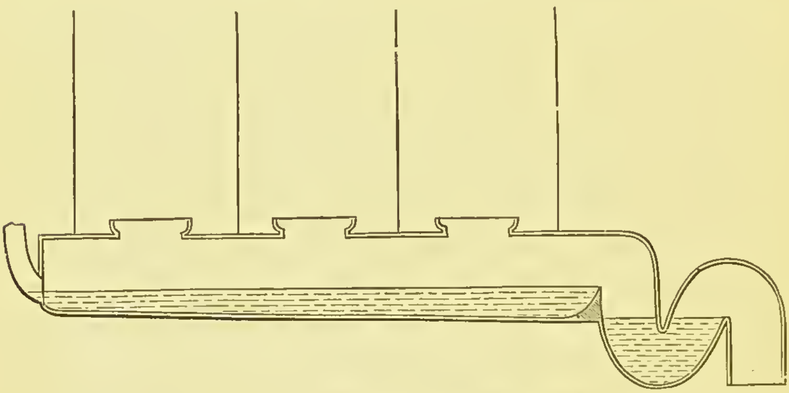


FIG. 13.—TROUGH WATER-CLOSET.

outer air, and not pass into the house, as so often happens when water-closets are placed in dark, unventilated corners. The division wall between the water-closet and a dwelling-room should always be of brick, and not a porous lath and plaster structure.

The *trough closet* (Fig. 13) is especially useful in large establishments, as hospitals, schools, workhouses, and asylums, and in the courts and alleys of towns. One apparatus serves for the use of several people at the same time, and the flushing can be rendered automatic. The closet consists of an open trough, usually of stone-

ware, with rounded bottom, of varying length according to the number of compartments desired. The trough should have a slight incline towards the drain; and by means of a weir at its lower end should be able to retain sufficient water to cover the bottom for its whole length. It should terminate in a siphon trap protected by a grid, to keep back articles improperly thrown in, before joining the drain. Each seat over the trough should be in a separate wooden compartment. The closet may be flushed by means of a Field's annular siphon flush tank (see Figs. 6, 7) of capacity proportional to the length of the trough to be flushed.

Trough closets might with advantage be more extensively used than they are in the poor districts of large towns, to replace the wretched "long hopper" basins, which are nearly always in a filthy condition and insufficiently flushed. The trough closet is well adapted to the wants of a very poor population living in courts and alleys, and using closets in common; the flushing is automatic, and if the tank is placed in a separate locked compartment, accessible only to the sanitary inspector, it is out of reach of mischievous interference. There is nothing in the structure of the trough that can be detached and misappropriated; and the closets of a whole court, consisting of a large number of families, can be supervised with great readiness by the sanitary official, and the contents disinfected during epidemic periods before being discharged into the sewer.

Slop closets, in which the excreta are carried away by means of the house waste waters, and flushing cisterns with separate water supply are not used, were originally introduced by Dr. Alfred Hill, M.O.H., Birmingham, and are now to be seen in many working-class houses in Midland towns.

The annexed figure (Fig. 14) shows a section through Day's waste-water closet. In this pattern the excreta fall into a stoneware tipper, which also receives the waste water. This tipper is so balanced on its bearings that when full it automatically tips over, and discharges its contents (fæces, urine, paper, and waste water) into the siphon trap below which leads to the

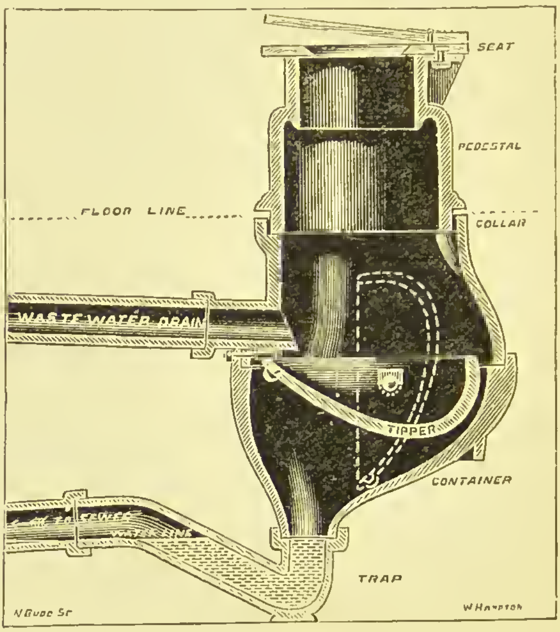


FIG. 14.—DAY'S WASTE-WATER CLOSET.

drain. The entrance to the siphon trap is considerably narrowed transversely, so as to prevent bulky articles improperly introduced finding their way into and obstructing the drain. The upper part of the closet is so constructed as to prevent, as far as possible, fouling of the sides above the tipping basin ; and this upper part can be taken down easily and removed for cleaning.

In another pattern of slop closet, the tipper is not

placed under the seat, but takes the discharge of the gully into which the house waste water empties itself. The discharge of water from the tipper flushes the drain in which the excreta are deposited direct from the closet.

The advantages of this system of slop closets are that clean water is not required for flushing, there is no delicate apparatus to be damaged and get out of order by rough usage, and both the primary cost and the outlay in keeping in repair are small. On the other hand, the economy of clean water and the absence of dilution cause the sewage passing from districts supplied with these forms of closets to be very strong and foul; and the difficulty of satisfactory treatment at the outfall of sewage of such potency is much enhanced. Economy of water is purchased at the expense of difficulties in the purification of the sewage. Moreover, they are liable to get foul and to block up, for in poorer class houses with no bath-rooms the slop waters may not be adequate to provide sufficient flushing.

The following rules are now usually followed in the erection of a new closet compartment: One of its sides, at least, must be an external wall; it must not be approached directly from any living-room, factory, or workshop, or compartment in which food is stored; there must be a window with an area of at least 2 square feet, the whole or part of which must open directly to the outside air, and in addition there must be means (as by an air-brick, etc.) of constant ventilation.

Urinals should be made of non-corrosive materials, such as china, slate, and stoneware; all metal apparatus is liable to corrosion, and should not be used. The floor should be cemented, and should slope towards a channel which discharges into a siphon trap connected

with drain or soil pipe. Urinal basins may be made of china or stoneware, constructed so as to retain water, and their waste pipes should discharge over the channel in the floor. The best kind of flush is that from siphon-action flush tanks which discharge automatically at regular intervals. Wright's self-flushing urinal is an ingenious invention which, by means of an arrangement of siphons in connection with the cistern, secures a flush to the urinal basin each time it is used.

Slop sinks should be used only where it is objectionable to discharge slops from bedrooms or hospital wards through the water-closets. They are usually capacious short hopper china basins with a siphon trap below, protected by a grid to keep back the larger foreign bodies which might obstruct the pipes. The trap should be connected with the soil pipe like a water-closet. They should be provided with a flushing rim, and flushed from a water-waste preventer.

Soil pipes are used to receive the contents of water-closets, urinals, and slop sinks only. They should be circular in section, and 3½ or 4 inches in diameter, these being the most convenient sizes for ordinary use. They should be of drawn, milled or rolled lead, 8 pounds to the square foot, or 9 pounds to the square foot for very high buildings, without any longitudinal seam, and should be fixed outside the house, with wiped (soldered) joints between the different lengths of pipe, each pipe being 10 feet in length. Lead T pieces are used to receive the branches from the water-closets.

Soil pipes outside the house are often made of light cast iron or galvanized iron. They are inferior to lead pipes, as the internal surface of iron pipes is much rougher than that of lead, and the joints as usually made with red lead putty are insecure. In America heavy cast-iron

soil pipes are insisted on by Board of Health regulations, especial precautions being laid down for the construction of the joints between the different lengths. To prevent oxidation and the formation of rust, iron soil pipes should be coated inside and outside with the magnetic oxide of iron (Barff's process), with hot coal-tar pitch, or with Angus Smith's solution. All cast-iron pipes must be free from holes or other defects, and properly tested, and of a uniform thickness of not less than $\frac{1}{4}$ inch. The joints between the different lengths must be caulked with oakum and molten lead, or with Spence's metal; and the joints between the iron pipe and the lead T pieces from the closets should be made with a brass ferrule, caulked in with lead, the lead pipe being attached to the ferrule by a wiped joint.

Joints of Lead Pipes.—In making a wiped soldered joint, the upper end of the lower pipe is opened out about $\frac{1}{4}$ inch with a turnpin. The lower end of the upper or male pipe is next rasped so as to make it fit into the opened-out end of the female pipe. The ends of the pipes which are to be covered with solder are next shaved with a shave-hook, so as to take the dulness off the lead and allow the solder to readily tin upon them.

Above and below the soldered line (Fig. 15) the pipes are then soiled round with plumber's soil (a mixture of lampblack and size) to prevent the solder adhering. It is well also to soil the insides of the pipes to prevent the solder adhering here and causing projections. The male end is next fixed into the female end, and a collar placed round the bottom of the joint to catch the solder as it falls off. The heated solder (a mixture of two parts of soft lead to one of tin) is then poured over the shaved ends of the pipes with a splash stick, and gradually worked into the right shape. A hot moleskin cloth is

now taken and wiped round the joint, so as to leave it of the shape shown in Fig. 15. As the pipes become heated by the solder splashed over them, the solder penetrates between the ends of the pipes, and readily adheres to all the shaved bright surfaces exposed, leaving when cool a homogeneous mass of metal. Fig. 16 shows a joint made with a copper-bit or blowpipe. The ends of the pipes are heated either with a copper-bit or blow-pipe, and when hot the solder is poured around the point of junction, and penetrates between the cut ends. A very

FIG. 15.

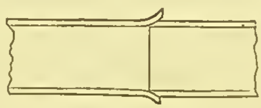


FIG. 16.

good joint is thus obtained with little trouble, but inferior in strength to the wiped joint with its strengthening band of solder.

The joints between iron pipes can only be caulked when the pipes are of sufficient substance and strength to stand it. The joints of the light iron pipes commonly used are made with spun yarn and red lead, or occasionally with Portland cement.

If lead soil pipes are used where much hot water is discharged through water-closets or slop sinks connected with them, owing to the expansion of the metal of the rigid pipe, twisting and contortion takes place, and such pipes readily wear out. Under such circumstances, either iron soil pipes should be used, or cast-iron pipes

lined with lead, or the lead pipes, if outside the house and not near windows, should have slip joints. For this reason, also, south and west aspects, involving much exposure to the sun, should be avoided for lead soil pipes.

With the precautions noted above, and under skilled workmanship, iron soil pipes may be used outside a house. Stoneware, zinc, or wrought iron should never be used for soil pipes: for stoneware is too heavy, and zinc is thin and liable, like iron, to erosions. The proper fixing of a lead soil pipe by means of ears or tacks to the walls of the house at intervals of 4 feet, to insure its being perfectly rigid, is a point of importance; if not securely fixed, there will be a strain on some or all of the joints, with the result of their becoming insecure. Outside soil pipes should be connected below with the house drain by a plain stoneware bend below the ground-level, a thimble of rough brass casting being wiped on to the lead pipe and a Portland cement joint being made between the brass and stoneware; and an iron soil pipe should be connected with the stoneware drain by receiving the spigot end of the iron soil pipe into the socket end of the stoneware drain, and making the joint with Portland cement. All soil pipes, whether inside or outside the house, should be carried up full bore above the entrance of the branch from the highest water-closet to the top of the house (Fig. 17) above the ridge of the roof, clear of all windows and chimneys, their ends being left open or covered merely with wire gauze to prevent birds from building in them. Where the soil pipe must be inside the house, it is sometimes thought desirable that it should not be connected directly with the house drain, but should discharge into a siphon disconnecting trap (soil pipe intercepter), with an air inlet outside

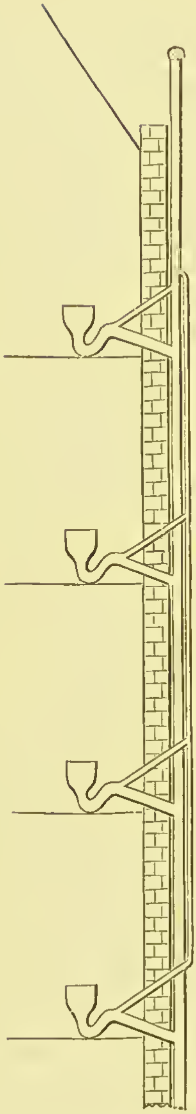


Fig. 17.—Soil Pipe and Ventilator, with Anti-siphonage Pipes from the Water-closet Branches.

the house—to admit of a current of fresh air passing up the soil pipe—the drain in these cases being ventilated separately by means of a 4-inch pipe carried up above the roof.

Where one soil pipe receives the discharges of several water-closets on different floors, the passage of the contents of one of the upper closets down the soil pipe may cause the water in the trap of one of the lower closets to be drawn off, owing to the suctional force of the downward current of air caused by the descent of the liquid in the soil pipe. To prevent this siphonage by suction taking place, a 2-inch lead ventilating pipe should be carried up from every branch pipe, a few inches beyond the trap (on its soil pipe side), and these anti-siphonage pipes should join with one another on their way up outside the house, and the common pipe may be carried up separately or taken into the ventilator to the soil pipe (Fig. 17). By this means the water-closet traps will not be disturbed by the passage of liquid down the soil pipe, for air will be sucked down

these anti-siphonage pipes to restore the disturbed equilibrium. Siphonage is most likely to occur in $3\frac{1}{2}$-inch lead soil pipes where the branch pipes from the water-closet traps to the soil pipe are long and curved. If they are short and straight, there is less likelihood of siphonage occurring. A trap at the foot of the soil pipe immensely intensifies suction siphonage. The long arms or branches from water-closets thus ventilated are relieved of foul air which otherwise accumulates in them.

Rain-water pipes from the roof should not be used as soil pipes and ventilators, for during heavy rain, when it may be most necessary to give a safe exit for displaced drain air, they will be useless as ventilators, and foul air from unventilated drains may be forced through water-closet traps into the houses.

House drains are usually constructed of circular glazed stoneware socketed pipes, 2 feet in length, with cemented joints (Portland cement). The pipes are also connected by Stanford's patent joints or Doulton's modification (which makes the pipes adjustable in any position), in which the spigot and socket ends of each pipe are provided with a mould of smooth plastic material, causing them to fit accurately into each other when in position, a very perfect joint being formed by greasing the prepared ends with a little rosin and melted tallow. These patent joints, however, are inferior to cement, as they are liable to erosion and decay, and are usually found not to be watertight some years after laying.

Stoneware pipes are less porous and more durable than earthenware pipes; the former may be distinguished from the latter by their colour (generally pale buff), the ringing note which they give out on being struck with a hammer, and their comparatively slight

increase in weight after twenty-four hours' immersion in water.

Portland cement is a mixture of chalk and clay burnt at a high temperature, and subsequently ground very fine. It is stronger and capable of bearing greater tensile strains than other cements (Roman and Medina), but does not set so rapidly.

When cemented joints are made, neat Portland cement only should be used, and care must be taken to remove any cement projecting from the interior of the joint into the drain, which when hardened would form an obstruction to the flow of sewage through the drain. Cast-iron pipes coated inside and outside with some preservative material such as the magnetic oxide of iron (Barff process) or Angus Smith's solution, to prevent oxidation, are used when the drain is required to be of extra strength, as when laid under roads or paths on which there is heavy traffic, and in soft, swampy ground. The joints of an iron drain must be caulked with lead and gasket.

When it is necessary to connect a lead to a heavy iron pipe, a strong brass ferrule or thimble should be jointed to the lead pipe by means of a wiped soldered joint; the brass ferrule is then received into the socket of the iron pipe and the joint made with hemp and molten lead.

For small and medium-sized houses a drain 4 inches in diameter is the proper size; for large houses a 6-inch drain may be used, and for institutions or establishments consisting of several buildings a 9-inch drain may be required. The smaller the drain, the better the flushing and removal of deposit; but the drain must in all cases be large enough to guard against blockage and to carry off at all times all the rainfall over the area drained, as well as the maximum flow of sewage proper of the

house. A volume of water sufficient to make a 4-inch pipe run full causes a 6-inch pipe to run less than half full, and a 9-inch pipe only about a quarter full, when all three are laid at the same inclination, since the sectional areas of the three pipes are in the ratio of about 1, 2, and 5.

The pipes must be laid (with the socket end pointing upwards towards the head or commencement of the drain) on a perfectly smooth incline of hard ground, or where passing under the basement of a house, on a bed of cement concrete, and in this case it is often the practice to cover and embed them as well with cement concrete. Concrete should be made of clean sharp sand, 1 part; clean ballast, 5 parts; Portland cement, 1 part. Each pipe should rest upon the concrete for its whole length, so that the drain may be truly laid, the lumen of each pipe being concentric with the next. The concrete should be hollowed out where the collar of the pipe rests, and the cement must be introduced all round the joint, below as well as above; and the joint should be finished with the trowel. It is sometimes the practice to introduce a strand of spun yarn into the interior of the joint to prevent the cement passing into the drain, and to insure the thickness of cement being the same all round. It is often the custom now to lay the drain on bricks at the bottom of the trench, and when the joints have been made with cement, to fill in with concrete beneath the pipes. If this is done, a brick should be used to support each end of every pipe, so that the drain may be truly laid.

The gradient of a 4-inch drain should, if possible, be not less than 1 in 40, of a 6-inch drain 1 in 60, and of a 9-inch drain 1 in 90; this will give in each case a velocity of flow of between 3 and 4 feet per second.

The drain should not, wherever it can be avoided, be carried under the basement of a house. Where, however, this is unavoidable, the special precautions noticed above must be taken, and at the point where the drain leaves the premises the wall should be supported by a relieving arch to prevent settlement and fracture of the pipes.

Drains should be laid as far as possible in straight lines. If a bend is necessary, it should be effected by means of a pipe curved to the proper degree, and the radius of any curve should not be less than ten times the cross-sectional diameter of the drain or sewer. A branch drain should be made to join the main drain by means of a V junction pipe, so that the branch current may be flowing nearly in the direction of the main current, thus causing no obstruction at the point of union. In large houses it is very often impossible to carry the drain in a straight line for its whole length. It is advisable in these cases, at every change of direction, to provide means of inspection by manhole chambers, the drain being continued through the floor of the chamber by a suitably curved channel pipe, *i.e.*, a pipe divided longitudinally in half. Into these inspection chambers (Fig. 18) the branch drains also should be made to discharge by means of short curved channel pipes emptying over the main channel. Winser's curved channel pipes, from which about a quarter section only of the circumference has been removed, should be used when connected with a high soil pipe, so as to avoid splashing of solid fæcal matters over the floor of the chamber; and where the drains are joined in a manhole, the invert of the smaller drain should be higher than that of the main by so much as the difference between the diameters of the two, so as to prevent the liquid flowing in the large

or main drain from backing up into the smaller. By this system of manhole or inspection chambers, the drain —which runs in a straight line from manhole to manhole —can be inspected and cleared, by rods, of deposit or obstructions, without breaking into it. Where it is necessary to connect a small pipe with a larger pipe, the junction should always be effected by means of a taper or diminishing pipe.

The *disconnection of the house drain* from the public sewer

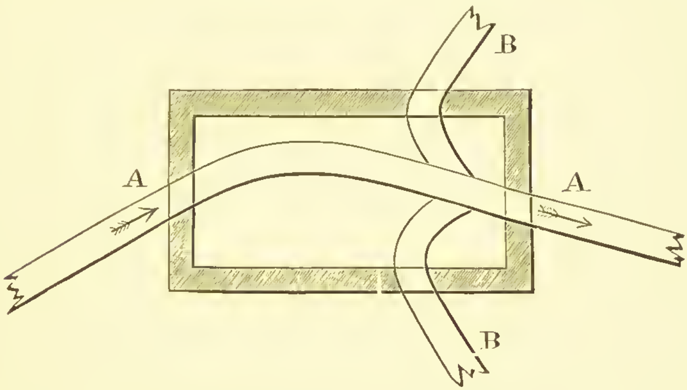


FIG. 18.—PLAN OF INSPECTION CHAMBER FOR HOUSE DRAIN, WHERE IT CHANGES ITS DIRECTION.

A, Main drain; B, branch drains.

is generally provided for, although it is not now generally held that sewer air is more specially harmful than drain air, the belief in the specifically infectious qualities of sewer air having been for the most part abandoned. Siphon disconnecting traps, however, prevent the passage of sewer rats up the house drains; and unless such traps are fixed, it would be impossible to provide for the ventilation of house drains by fresh-air inlets as now practised. Disconnection is effected by interposing a siphon trap between the house drain and the sewer, and on the house side of the trap a means of inlet for fresh

air into the house drain is provided. The point usually chosen for disconnection is immediately before the house drain leaves the premises in its course to the street sewer. If the house drain is provided with a ventilating pipe at the further end, air, admitted on the house side of the disconnection trap, will generally produce a current from the lower opening to the higher, and a circulation will thus be established in the drain and soil pipe, preventing any accumulation of foul air.

The simplest form of disconnecting apparatus consists of a siphon trap with fresh-air inlet formed of stoneware pipes on the house side of the water-seal. There are several varieties of this sort of trap sold, under the names of "sewer-air intercepter," "sewer-air trap," etc. The points to be observed in choosing a trap of this description are: (1) Where the drain is a 6-inch or a 9-inch pipe, the siphon should be a size smaller than the drain; (2) there should be a fall of 2 inches or more from the level of the discharging end of the house drain to the surface of the trapping water; (3) the siphon should provide an adequate seal of 2 or 3 inches of water; (4) the inlet to the siphon should be nearly vertical, whilst the outlet rises at an angle of not more than 45°. These qualities, except (3), are necessary to insure efficient flushing of the trap; and, to further attain this end, the drain should be laid with a slightly greater fall before its junction with the trap. The fresh air inlet to the siphon is continued up by a vertical pipe to a little above the surface of the ground, and there covered by an open iron grating.

In larger houses it is now usual to provide a *disconnecting manhole chamber* (Fig. 19), instead of the simple trap above described. The chamber walls are built of brickwork rendered in cement, and the floor is made of

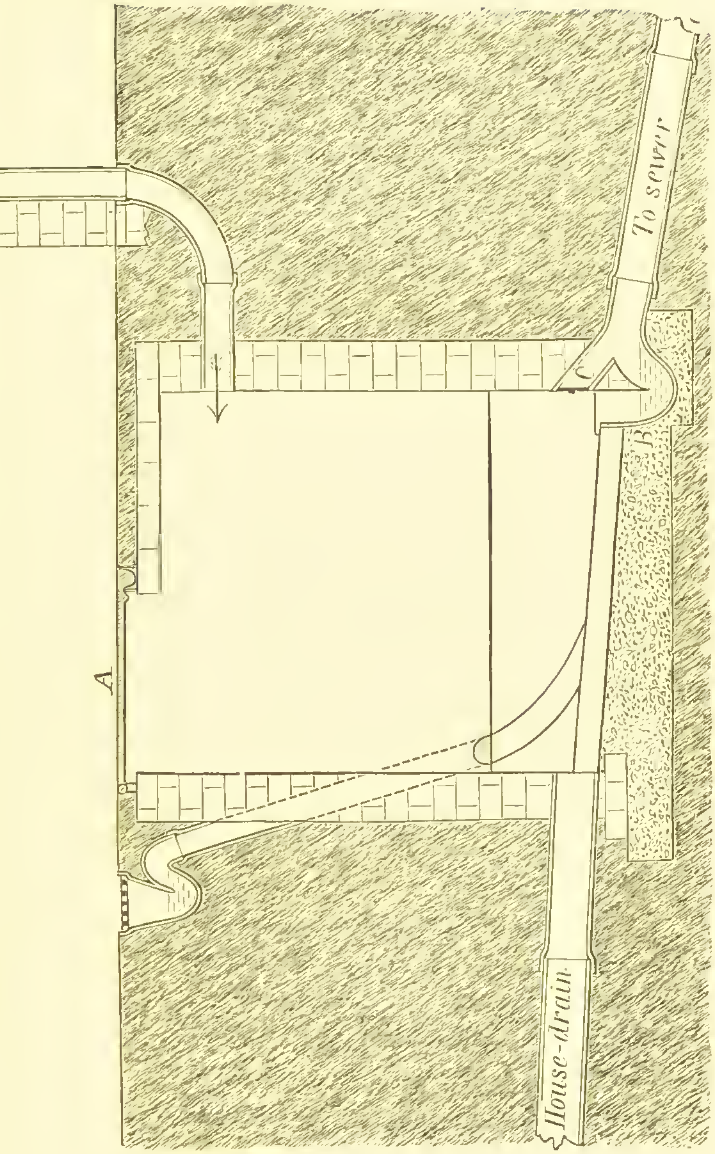


FIG. 19.—DISCONNECTING MANHOLE CHAMBER ON HOUSE DRAIN, WITH FRESH-AIR INLET.

A, Air-tight iron cover; B, siphon trap; C, raking arm.

concrete. The drain is continued through the floor of the manhole in the form of a glazed channel pipe, from which the floor—made of cement—slopes up at an angle of 30°

to the brick walls of the manhole. The branch drains, in the form of suitably curved ($\frac{1}{2}$ or $\frac{3}{4}$) channel pipes, are made to discharge over the main channel, which itself discharges into a siphon trap. The siphon trap should be provided with a " raking " arm, one end of which opens into the manhole, the other end being connected with the drain beyond the trap. This arm is to permit of obstructions being removed from the drain between the siphon trap and the sewer; when not in use, the manhole end should be closed with a tile or piece of slate set in cement. The manhole chamber may be closed above by an air-tight iron cover; and the fresh air should then be admitted into the chamber by a 6-inch pipe, the manhole end of the pipe being opposite the entrance of the drain, whilst the end open to the air is covered by an iron grating and provided with mica flaps, which permit air to pass in, but prevent the reflux of foul air. Where the disconnecting chamber is some distance from the house, fresh air may be admitted by perforations in the iron cover. The chief advantage of the manhole chamber is the readiness with which the drain can be inspected and cleansed.

Wherever possible, the plan of drainage should be so designed as to provide for all manhole chambers being situated in yards or open areas, and not actually within the walls of the house. There is generally some danger of escape of drain air through covers which are not perfectly air-tight. It is important also that the interiors of manholes should be rendered in cement, so as to be water-tight, as, if the disconnecting trap becomes choked, the chamber may become filled with sewage.

For house drains with insufficient gradient, in which deposit is liable to occur, it is advisable to provide an automatic flush tank to discharge into a gully at the

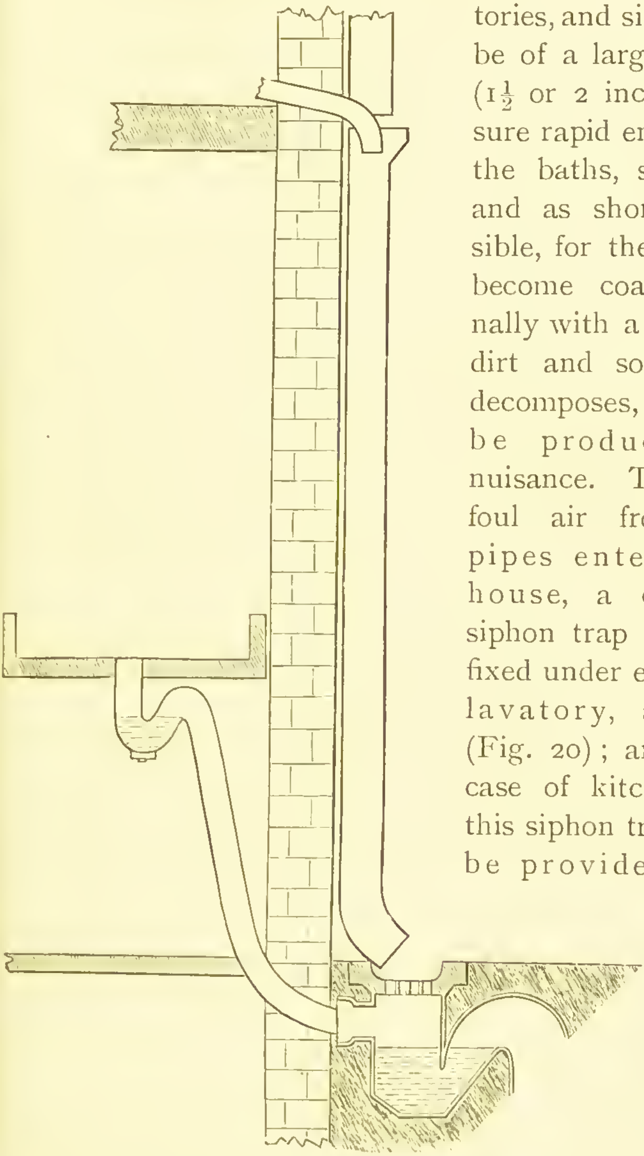
head of the drain; by this means the dangers arising from insufficient fall may be to a great extent obviated.

When a house drain has been laid, and before it is covered in, it should be tested for leaks. A simple method is to plug the lower end of the drain in the disconnection chamber and fill the drain with water. Expanding plugs with india-rubber rims are now made to suit various sized pipes. If, after the water has risen into an inspection chamber or gully at the head of the drain, on stopping the flow, the level of the water does not remain stationary, but falls, the drain is not water-tight, and the joints should be examined for leaks. If there is no disconnecting chamber, there is no alternative but to open up the drain just before it leaves the premises, and remove a length of it in order that the plug may be inserted. It is sometimes the practice also to pass a spherical wooden ball $\frac{1}{4}$ inch less in diameter than the drain through the pipes, to ascertain that there are no projections of cement from the joints; and this should always be done at the time the drains are laid. Another method, which tests the soil pipes as well as the drains, is to burn brown paper or oily cotton-waste in the disconnecting chamber, the air-inlet being closed as soon as the paper or waste is well alight; or the drain may be filled with smoke by a forcing apparatus actuated by an air-pump, or by firing smoke rockets into it. The smoke apparatus is preferable to the rocket, since by its use it is possible, after stopping up the open end of the soil pipe ventilator, to expose the drain and soil pipe to the test of smoke *under pressure.* Leakages in the drain or soil pipes will then become evident to both sight and smell. A third method, which is especially applicable for testing soil pipes and drain connections which have been long in position, and where there is no disconnection apparatus, is to pour

down the highest water-closet about $\frac{1}{2}$ ounce of oil of peppermint, following it up with several gallons of hot water. By this means the smallest leak will be discovered by the sense of smell, as the peppermint is excessively volatile. Drain grenades containing a composition of asafœtida and phosphorus, which explodes on contact with water, giving rise to very pungent gases, are in a similar manner used in drain testing. The pneumatic test for drains has much to recommend it. The test is applied similarly to the smoke test, but, instead of smoke, air is pumped into the drain under pressure, and it is noted if the gauge continues to record the same pressure for some minutes. Soil pipes and their branches may be tested, before the water-closets are connected, by soldering over the apertures where the traps of the water-closets are to be connected with the soil pipes, and then filling with water. This is a severe test, owing to the great head of water, and one rarely applied; but strong lead pipes are found to stand the test well if the joints are properly made, and if a brass thimble is first soldered on to the lower end of the soil pipe.

It is important to note that whenever a water test is applied to drains or soil pipes, air is liable to be imprisoned in the branch pipes or drains as the water rises; and that provision must be made for the escape of this air by passing a bent pipe through the gully or trap which imprisons the air, otherwise the water-level will fall somewhat, as the air gets absorbed under the pressure, and its place is gradually occupied by the water, although the pipes may be quite water-tight.

All *waste pipes* from baths, lavatories, sinks, and safe-trays under water-closets or baths must be disconnected from the drain or soil pipe by being made to discharge into the open air. The waste pipes from baths, lava-



tories, and sinks should be of a large diameter ($1\frac{1}{2}$ or 2 inches) to insure rapid emptying of the baths, sinks, etc., and as short as possible, for they tend to become coated internally with a deposit of dirt and soap, which decomposes, and may be productive of nuisance. To prevent foul air from these pipes entering the house, a cast-lead siphon trap should be fixed under every bath, lavatory, and sink (Fig. 20); and in the case of kitchen sinks this siphon trap should be provided at its

FIG. 20.—DISCONNECTION OF RAIN-WATER AND WASTE PIPE OVER SIPHON YARD GULLY.

lowest point with a screw cap, capable of removal, in order

to clear the trap of sediment and grease. The waste pipes from the upper floors are usually carried through the external walls to discharge into the open head of a rain-water pipe (Fig. 20), divided, if necessary, into lengths for this purpose; but this is not a very good plan if the open heads are anywhere near windows, for the iron pipes become in course of time much fouled from soap and dirt, and then are apt to smell offensively. In such cases the 2-inch lead waste pipe should be continued down to the gully at the ground level, its upper end being carried up to the roof and left open; anti-siphonage pipes will be required in some cases, especially where several waste pipes on different floors discharge into a main waste pipe. Every rain-water or waste pipe must be disconnected from the drain at its foot by opening on the iron grating over a stoneware siphon yard gully. The basement waste pipes may discharge into yard gullies by side-inlets (Fig. 20). When it is impossible to avoid having a long waste pipe, this must be ventilated by a pipe of its own diameter carried up outside the house to a convenient point. Whenever it is necessary to place waste or other pipes within partitions or recesses in walls, they should never be covered, except with wood-work, which should always be made readily removable.

The *overflow pipes of cisterns* should be made to serve as "warning" pipes, by being carried through the external wall and left open at a point where any escape of water through them would be observed.

The *surface water* from yards and areas should be carried off by those siphon gullies which receive the waste waters from the house (Fig. 20), because these gullies are always efficiently trapped in dry weather. Yard gullies used for surface water only, become untrapped in dry weather, owing to the evaporation of the water in them. These

siphon gullies are connected with branch drains which join the main drain in the inspection or manhole chambers before referred to; they require to be cleansed periodically of sand and dirt, which collect at the bottom of the trap.

In large houses it is found that the mineral matter and grease discharged through the kitchen or scullery sink are apt to lodge in the drain from the gradual solidification of the grease as the water cools, and so form an obstruction. It is usual in such cases to cause the waste pipe (2-inch pipe, trapped under the sink) to discharge

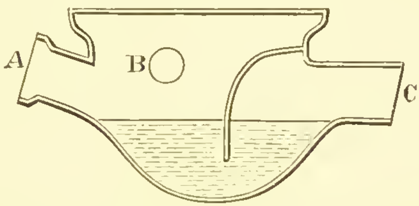


FIG. 21.—FLUSHING GULLY FOR GREASE.
A, Connection with flush tank; B, entrance of sink waste pipe; C, connection with drain.

into a *grease gully* instead of into a yard gully. This *grease gully* is made of stoneware (Fig. 21) and may with advantage be connected with an automatic siphon flush tank. The hot water from the sink is cooled on entering a large volume of cold water in the trap, the grease solidifies and rises to the top, whilst the sand sinks to the bottom of the trap. When the flush tank discharges, the grease is thoroughly broken up by the sudden inrush of the large volume of water, and is then carried along through the drain without any opportunity being given to it to deposit on the sides or floors of the pipes. The grease gully should be covered above by a grating, and sunk a little beneath the surface of the adjoining ground to confine all splashings to the trap.

To carry off the water used for washing down laundries, sculleries, and dairies, the floors should slope to a channel leading to a yard gully outside the house ; in some cases it is necessary to provide a drain, which should be protected by an Antill or some form of iron lip trap at the end inside the building, whilst the other end discharges into a yard gully by a side-inlet.

The house drainage arrangements described above have for their object : (1) the speediest possible removal from the house to the public sewer of excretal and other refuse by means of water ; (2) the prevention of deposit of foul matter in any part of the drainage system, and of percolation into the soil of polluting liquids ; (3) the establishment of a current of air through every part of the soil drains and pipes, in order to disperse any foul gases that may form, and allow them to escape with safety into the open air ; (4) the prevention of any entry of gases from soil pipes, drains, and waste pipes, into the house ; (5) the exclusion of the air of the common sewer from the house drain and the house.

Objects (4) and (5) are to a great extent attained, as we have seen, by means of traps or water-seals, and the question arises, "How far do such traps carry out the objects for which they are designed ?" Siphon traps are the most cleanly of all traps, because they present no corners or angles where deposit can accumulate, and are most easily flushed clean. Their liability to siphonage we have considered, and we have endeavoured to show that it can be obviated by a sufficient depth of siphon providing an efficient seal of water, and by adequate ventilation. There is, however, another disadvantage common to all water traps, which is that the water will absorb gases on one side of the trap, and give them off on the other, so that foul air from the drain or sewer may

be given off—only, however, to an inconsiderable extent—into a house, notwithstanding the presence of the trap. The only remedy for such a state of things is the prevention of foul air accumulations by adequate ventilation. We have seen that this is possible in properly designed house drainage, and it only remains for the public authorities in charge of the public sewers to take the necessary precautions to prevent the formation of foul gases in the sewers, or to disperse them when formed. The proper ventilation of drains and soil pipes can only be effected where there is an inlet for fresh air at one end of the system, and an outlet for foul air at the other end. Where there is an outlet but no inlet, the pipes must be always full of foul air, though not under pressure, for there can be then no renewal of the air in them by the passage of fresh-air currents.

Defective Sanitary Arrangements in Houses.

In examining houses, all sorts of appliances and arrangements will be found, departing more or less from the sound principles we have laid down, and we will now briefly describe a few of the sanitary defects more commonly found in houses.

Drains, rectangular, barrel, or oval in shape, constructed of bricks set in mortar without any cement, and of large size (18 inches or more in diameter), are not unusually found running under the basements of houses, and are sometimes connected with cesspools in these positions. These brick drains, although originally intended only to carry off surface and house waters, will be found to receive the water-closet discharges as well. They invariably leak, for the mortar becomes loosened from the bricks, and water finds its way out through these open

spaces; in some cases all the liquid leaks out of the drain to saturate the surrounding soil, whilst the solids accumulate in the drain until it is completely blocked. As the brick drain communicates directly with the sewer, rats find their way into it, and, pushing through the loosened bricks, form runs under the house, and sometimes into the larder, which become passages for foul air. To ascertain if a brick drain exists under a house, the ground must be taken up; or the sewer can be entered, if large enough, and the drain examined where it joins the sewer.

Pipe drains are always preferable to leaky brick drains, but all sorts of mistakes are made in laying pipe drains, and the resulting evils are similar to those arising from brick drains. In the first place, the pipes may be of improper material, such as unglazed porous earthenware, and without proper sockets. If glazed stoneware socketed pipes are used, the drain may be laid for the whole or part of its length with insufficient fall, or with a fall the wrong way. Again, the pipes used may be, and generally are, much too large—9-inch pipes where 4-inch would be sufficient; or the pipes may be laid the wrong way (Fig. 22), with the socket end downwards or towards the sewer.

The pipes are sometimes laid dry, *i.e.*, without any luting material in the joints, or the luting material used may be clay, which is soon washed out of the joints. Even where the joints are luted with cement, if the drain is laid on uneven ground, settlement takes place, and the cement joints become cracked and leaky.

Bends in drains are often made by fitting straight pipes into one another, the result being an open joint on the side with the greater curvature. The junctions of branch drains are frequently made by knocking a hole in

one side of the main drain sufficiently large to receive the end of the branch, which projects more or less and constitutes an obstruction, the hole being filled in with clay or cement. Even where proper junction pipes are used, the junction may be made the reverse way, so that sewage from the branch enters the main drain in a direction opposed to the flow of sewage in it.

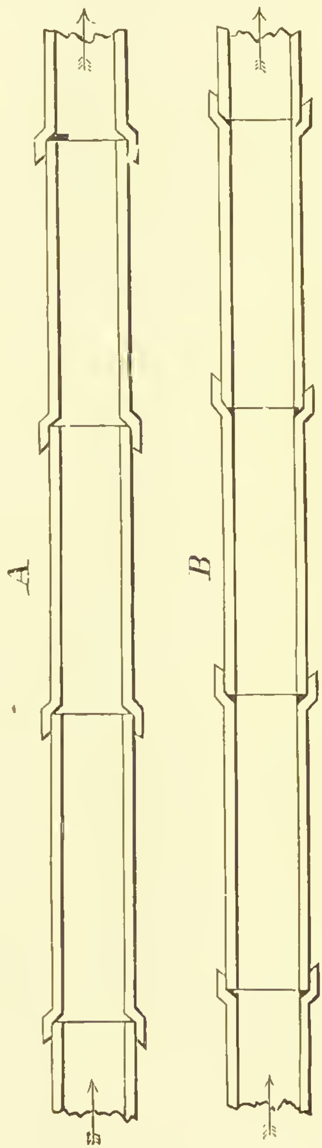


FIG. 22.—A, DRAIN LAID THE RIGHT WAY; B, DRAIN WRONGLY LAID.

Where a small pipe joins a larger pipe, the junction is often effected without a diminishing pipe by placing the socket end of the small pipe into the socket of the larger pipe, and the joint that results is most defective (Fig. 23). In this case also, the smaller pipes will be all laid the wrong way (with the socket end downwards), and junctions will be wrongly connected in a direction opposed to the flow of sewage. The evils arising from such defects in drains are leakages of foul liquid into the soil, escape of foul air, and formation of foul deposits in the drains, leading eventually to complete obstruction.

House drains were, and are still, commonly connected

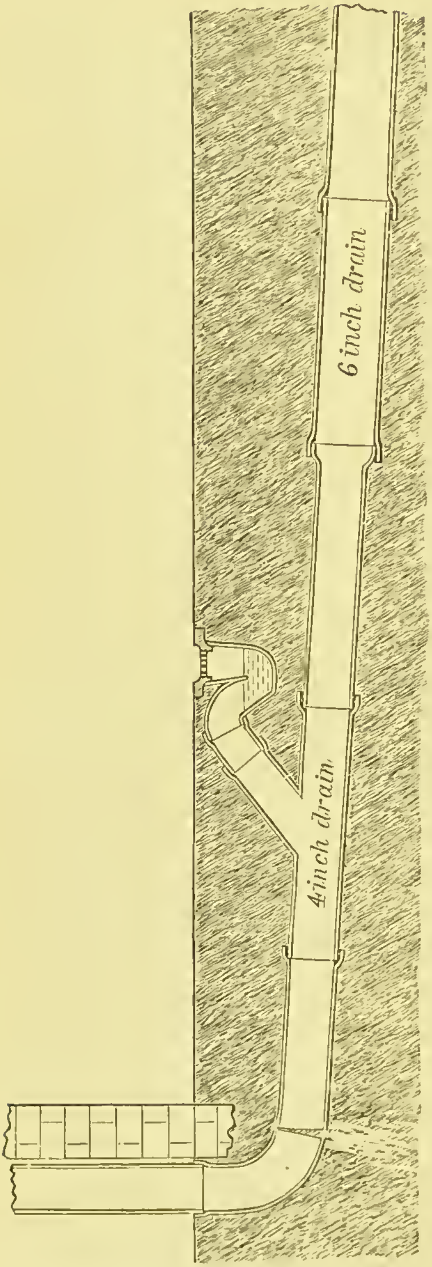


Fig. 23.—4-inch Drain laid the Wrong Way for Want of Diminishing Pipe.

directly with the common sewer, an iron flap trap only being placed over the opening of the drain into the sewer. This flap trap affords no protection against the passage of foul air or rats from the sewer into the drain. It was formerly the custom to place a *dipstone trap* (Fig. 24) on the course of the drain to prevent the passage of foul air up it. It consisted of a brick chamber of some depth retaining liquid, into which dipped a stone fixed in the roof of the trap. This trap not being self-cleansing, because the upper part of the trap, though soiled with splashings, is never flushed, becomes choked with deposit, which putrefies and causes a most offensive nuisance. Where disconnection is practised, it is not uncommon to find siphons too large, or of improper construction, and

incapable of complete flushing ; in some cases the siphon is so constructed that the outlet is higher than the inlet, with the result that the sewage is backed up in the drain (Fig. 25). One of the worst forms is that in which a vertical access pipe rises from the dip of the trap, for in this pipe solid matters are bound to accumulate.

Soil pipes are very commonly found fixed inside the house. If of lead, the pipe may be longitudinally seamed

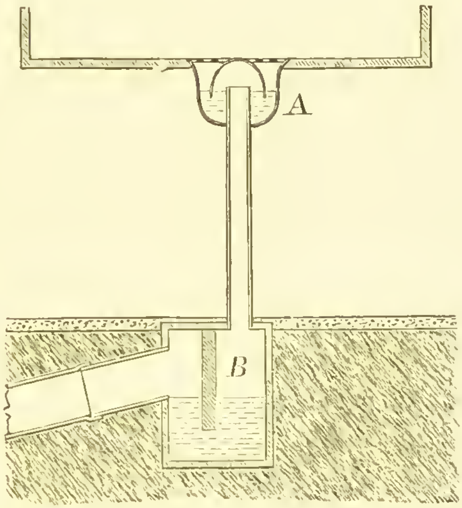


FIG. 24.—SINK WITH DOUBLE-TRAPPED WASTE PIPE.
A, Bell trap ; B, dipstone trap.

for its whole length, with perforations in the seam of solder, and the joints may be formed by slipping one length of pipe inside the other. Cast-iron pipes with loose packed joints occasionally do duty as soil pipes, and may perhaps take rain water as well. Zinc is sometimes used for soil pipes ; where it has been long in use, it is sure to have numerous perforations. In old houses the soil pipe is almost invariably unventilated ; that is to say, it is not open, but closed at its highest

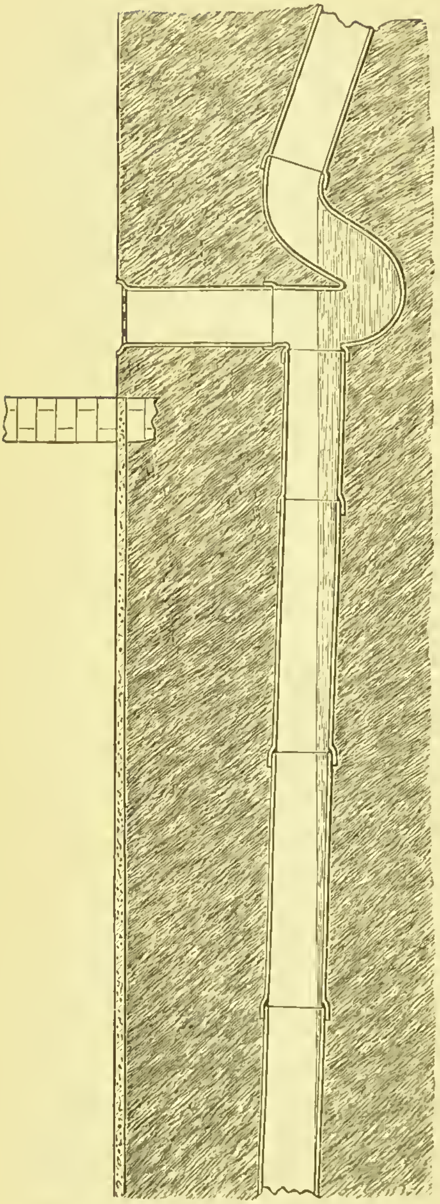


FIG. 25.—DISCONNECTION TRAP WITH OUTLET HIGHER THAN THE INLET.

point. The foul air in unventilated pipes acts on the lead (or zinc) walls, and gradually, by erosion, forms holes through which foul air or liquids escape. But such closed soil pipes are often in reality—though not so intended—ventilated into improper places, for the foul air in drain and soil pipes is sure to find some way out. Where the waste pipes of baths, sinks, or lavatories are connected directly with the D trap under a water-closet, with the soil pipe, or with the drain, foul air will find its way out through these waste pipes, or through bell traps into the house. Another ready means of exit of foul gases is the waste pipe to the safe-tray under a bath or water-closet, when this is connected with the soil pipe or drain.

But the most important, because the most dangerous, is the direct connection of the overflow or standing

waste pipe of a cistern used for drinking water with the drain or soil pipe (Fig. 11). The foul air rises through this pipe and escapes under the lid of the cistern over the surface of the water, which readily absorbs foul gases and collects suspended matters, and a dangerous pollution is thereby caused. Other means by which foul air can escape from unventilated drains are bell traps (Fig. 24) in the basement of the house (kitchen or scullery), or in yards and areas, and rain-water pipes directly connected with the drains. In this last case also, foul air will escape through any loose joints of these pipes, which may be in close proximity to bedroom windows.

With an unventilated drain, water traps—even the best designed, as we have already seen—are not effectual safeguards against foul air entering the house. Bell traps, which present so small a seal of water, and which are usually choked with rubbish, are worse than useless to prevent the passage of foul air. It is very usual, too, to find the bell removed and the trap consequently gone, because the obstruction to the flow of water through them is so great. The aspirating effect of fires inside a house must not be lost sight of; the draught up the chimney tends to draw air towards it, from any opening, into the room; and thus it often happens that drain or sewer air is drawn into the living rooms.

Where some attempt has been made to ventilate the soil pipe, it is often either most absurdly inadequate, as when a 1-inch pipe is carried up as ventilator to a 4-inch soil pipe, or it is improperly carried out, as when a rain-water pipe is led into a soil pipe to also act as ventilator. Besides the danger of foul air escaping into windows, especially attic windows under which the rain-water pipe often commences, it is obvious that during a storm of rain, when it is most necessary to provide a safe means

of exit for displaced drain air, the ventilator may be running full of water, and will be useless.

The pan closet and D trap are perhaps the most common of all sanitary (or insanitary) appliances. They should, wherever found, be replaced by improved forms of closet and trap. The pan closet is usually supplied with water from the same cistern that supplies drinking water, the supply pipe is connected with a small service box at the bottom of the cistern (*vide* Fig. 11). Water is admitted into the service box by a spindle valve guarding an opening in the top of the box, this valve being connected with the handle of the water-closet by wires and cranks, and an air escape pipe rises from the service box to give exit to displaced air. When the handle of the closet is pulled up, the spindle valve is raised from its seat, water enters the service box, and air is forced up the escape pipe to be discharged over the surface of the water in the cistern. Now, the supply pipe and service box are always full of air, which, ascending from the closet basin, is often much befouled, and it is this air which escapes over the water of the cistern, and may impart to it dangerous qualities. For water is capable of dissolving foul gases in contact with it ; and it is this property which often imparts such an offensive smell to the water of cisterns supplying pan closets, or of cisterns with overflow pipes connected directly with D traps or soil pipes.

Hopper water-closets are often found to be supplied with water direct from the house main. During an intermission of the water service, the tap may be left open, and foul air or liquid filth may at such times be sucked up from the closet basin into the water pipes. Several severe outbreaks of enteric fever have been attributed to this cause.

Sewers.

Sewers are underground channels designed to receive and convey away by gravitation the rainfall and waste waters of the town, and, where the water-carriage system has been adopted, excretal refuse as well. In former times, and in some towns at the present day, as at Dublin, if a river or stream pass through or near a town, the sewers took the shortest available course to the banks of the stream, and there discharged—each sewer by its own outfall. When it became no longer possible for towns to discharge their crude sewage into streams in this manner, intercepting sewers of large size had to be constructed to receive the sewage of the tributary sewers; and these intercepting sewers, when united to form one or more main outfall sewers, conduct the sewage outside the town.

As we have already seen, brick sewers, as originally constructed, perform a double function; they are land drains as well as sewers: for, not being constructed water-tight, they drain the soil by admitting subsoil water, and they may also be used to convey away the sewage. By permanently lowering the level of the subsoil water in towns, these sewers have had an important effect in improving the health of the inhabitants.

But the beneficial influence of sewers acting as drains has an undoubted drawback, viz., that drain sewers will just as readily permit of foul liquids percolating out of them through their walls to pollute the surrounding soil and contaminate ground water and ground air in the neighbourhood, as of subsoil water entering them. That such escape of foul water does take place is plainly shown by the fact that in London, with its drain sewers, all shallow-well waters have been found to be polluted

with sewage, and the wells have in consequence been closed. The pollution of the ground air has also an important bearing on health, as such air is liable to be drawn into houses whose basements are not thoroughly concreted over. It is now the practice of all engineers to construct sewers as far as possible water-tight, and to provide other means for draining the soil. The drainage of the subsoil, being so important a consideration from its bearing on the public health, must not be lost sight of in those towns which, by reason of a low situation or a high impervious subsoil, have the underground water but a few feet from the surface.

The Combined System.—In this system the sewers are designed to receive the rain—or such part of it as does not evaporate or is not retained by the soil—falling over the area covered by the town, as well as the sewage proper. The amount of evaporation depends largely on the temperature of the air; but even in summer it is found in towns, where a large part of the surface exposed to rainfall consists of roofs and paved surfaces of yards, courts, and streets (especially also where there are steep gradients), that from one-half to three-quarters of the rain falling reaches the sewers. It is therefore necessary to construct the sewers of size sufficient to take a large part of the rain falling during heavy storms, such as $\frac{1}{2}$ inch of rain in one hour in towns, and $\frac{1}{4}$ to $\frac{1}{3}$ inch in the suburbs and less populous parts; otherwise, if no storm overflows are provided, the sewers in low-lying districts are overcharged, and cellars and basements are flooded. In London the intercepting sewers were constructed to receive $\frac{1}{4}$ inch of rain over the whole area sewered in twenty-four hours (including subsoil water); but storm overflows direct into the Thames relieve these sewers during heavy storms. When a

storm occurs after a time of drought, the sewers are flushed of accumulated deposit, and the sewage which escapes by the storm overflows is often very strong and foul, and productive of nuisance in the river. At high-water, too, the storm overflows are tide-locked, and then low-lying districts may be flooded.

This principle of the interception of sewage is also commonly practised in seaside towns where the original sewers have been given a direct course to the sea, and the escaping sewage gave rise to offence. The intercepting sewer running along the seashore picks up the original sewers, and conveys the sewage to its outlet some distance away from the town. Such a main outfall sewer discharging into the sea should terminate below the water-level, even at low-tide, and should have the outlet protected by a flap valve.

To prevent deposit, sewers should be rendered self-cleansing by being constructed with a sufficient gradient, and of a size suitable to the volume of sewage which they will ordinarily be required to carry. According to Mr. Baldwin Latham, sewers of from 12 to 24 inches diameter should have a gradient sufficient to produce a velocity of not less than 2½ feet per second, and in sewers of larger dimensions in no case should the velocity be less than 2 feet per second. For large sewers a less gradient is required than for small sewers to produce the same velocity; but the volume of the sewage to be conveyed must be very much greater for the large than for the small sewer. A sewer 10 feet in diameter having a fall of 2 feet per mile; a sewer 5 feet in diameter having a fall of 4 feet per mile; a sewer 2 feet in diameter having a fall of 10 feet per mile; and a sewer 1 foot in diameter with a fall of 20 feet per mile, will all have the same velocity of flow, but the volume of sewage in the

10-foot sewer must be 100 times, in the 5-foot sewer 25 times, and in the 2-foot sewer 4 times, the volume of sewage in the 1-foot sewer.

To calculate the discharge from sewers, the following formula is generally used :

Let V = velocity of flow in feet per minute.
,, D = hydraulic mean depth.
,, F = fall in feet per mile.
Then $V = 55\ (\sqrt{D \times 2F})$.

If A = sectional area of current of fluid, $V \times A$ = discharge in cubic feet per minute. The hydraulic mean depth is the sectional area of the current of fluid ÷ the wetted perimeter (*i.e.*, that part of the circumference of the sewer wetted by the fluid flowing through it) ; in circular sewers running full or half-full it is one-fourth the diameter. The term when applied to a sewer implies the depth of a rectangular channel whose sectional area equals that of the curvilinear channel under consideration, and whose width is equal to the entire wetted perimeter of the latter.

In modern systems of sewerage, the sewers are laid in straight lines with manholes at every point of change of direction. The inspection and cleansing of the sewers is much facilitated by such an arrangement. The best form of sewer in all cases in which the volume of sewage undergoes fluctuation is the egg-shaped, the small end of the egg downwards. In this form, there is a greater depth of sewage and less contact with the walls of the sewer, and consequently less friction, than in any other form. For outfall sewers, in which the volume of sewage to be conveyed is large and uniform, Mr. Baldwin Latham advises the circular form, as it is cheaper and stronger when constructed. Up to 18 inches internal diameter, sewers should be circular in section ; and for

these small sizes, stoneware, cement, or concrete pipes are better than sewers constructed of brick. Iron pipes and patent joints in stoneware pipes are often used in damp sites. The iron pipe has the advantage of being made in 9 and 12 feet lengths, and therefore fewer joints are necessary; it can also be jointed to stand a great pressure. Mr. Latham's experience is that no public sewer should be less than 9 inches in diameter, owing to the risk of smaller pipes becoming obstructed and stopped up by articles improperly introduced into the house drains.

Sewers with unequal areas should not join with level inverts; but the bottom of the lesser sewer should have a fall into the main at least equal to the difference between the diameters of the tributary and the main sewer.

Well-burnt, tough, impervious bricks, or glazed fire-bricks, should be used in the construction of sewers, especially in the construction of the lowest segment or invert of the sewer, which is the part most liable to wear and erosion from the passage of stones and grit in the sewage over it. For the smaller sewers suitably curved bricks only should be used. Sewers under 3 feet in diameter, when laid in good ground, may be constructed of 4½-inch brickwork. When laid in bad shifting ground, or for larger sewers, 9-inch brickwork should be used. Suitably curved stoneware blocks are now very generally used for the inverts of sewers; their smooth hard upper faces form an excellent floor for the sewer. When these blocks are made hollow, they provide a means of draining off the subsoil water during the construction of the sewer; but engineers do not now advise their use, as the hollow block is apt to split from the weight of the sewer built over it; and in sandy soils the washing away of sand in the subsoil water passing into the subsoil drain may

cause settlement of the sewer. The mortar used in jointing the bricks should be made of the best Portland cement and fine sharp sand.

The Separate System.—Where it is intended to convey away sewage proper only, storm, surface, and subsoil waters being separated, the sewers need be only of small size. Under such circumstances glazed stoneware pipes, jointed with Portland cement, are generally used to form the tributaries, whilst the outfall sewer is constructed of brickwork. Cement or silicated concrete pipes have been used, especially in Germany, instead of stoneware pipes. They are said to be less brittle, to withstand extremes of climate, and to resist the chemical action of the sewage better than stoneware pipes. Under the separate system, the sewers, of whatever material, must receive water-closet sewage and waste waters only; all rain water from roofs, yards, or areas, must be conveyed by separate pipes into surface channels at the sides of the streets, when the gradients are sufficient, or into underground channels constituting a system of drains quite distinct from the sewers. At convenient points the surface channels or underground drains should discharge into the stream or river which forms the natural drainage bed of the locality. The drainage of the subsoil should be effected by agricultural tile drains laid in the same trench, but above the sewers, and diverted into the water-courses at all suitable points.

The advantages of the separate system are: (1) The volume of sewage to be conveyed outside the town is small as compared with that to be dealt with by the combined system; its daily or seasonal fluctuations, and the total quantities to be dealt with, can be calculated approximately from the population and water-supply (points of great importance where the sewage has to be

pumped to the outfall, or to be purified before being discharged); (2) the sewage is uniform in composition because protected from dilution with storm waters, and its purification and utilization day by day are therefore undertaken with much less difficulty than is the case with sewage which is sometimes strong and at others very weak, from admixture with rain and subsoil waters; (3) the sewers, being small and having smooth walls, are more frequently flushed, and there is less tendency to deposit, with formation of foul gases, than in the case of the larger brick sewers; (4) the cost of the system is very much less than that of the combined system.

The disadvantages are: (1) that every house must have two drains or two sets of pipes—one for sewage and the other for rain water; and this gives rise to mistakes on the part of builders, who occasionally connect the pipes with the wrong system; (2) that the surface water from yards and streets is often foul, especially when a storm succeeds a period of drought, unless the yards and streets are constantly cleansed and well scavenged; (3) that the flushing effect on the sewers of storm waters is lost. It is, however, sufficiently obvious that these disadvantages in no way counterbalance the undoubted advantages of the separate system.

Inspection, Flushing, and Ventilation of Sewers.

In any system of sewerage it is necessary to provide means of access to the sewers for their cleansing and for the removal of accumulations of deposit. Manholes are shafts sunk from the surface of the road to the sewer, by which the scavengers can descend. They are constructed of brickwork, and provided with a locked iron door at the street-level. In streets where there is much traffic, the

shaft is sunk from the footway perpendicularly for a short distance, and then carried down by means of steps to the side of the sewer. In other cases the manholes are sunk from the middle of the road to the crown of the sewer. They have also a variety of other uses; they are used as points of junction between tributary pipe sewers and the main sewer, curved channels being constructed in the floor of the manhole; and they are also the points at which flushing gates may most advantageously be fixed in brick sewers.

Flushing gates are sluices made to fit the whole or part of the sectional area of a sewer. When in position they dam back the sewage in the sewer above, and on being raised, or liberated, the sewage so stored rushes forwards and effectually flushes the sewer below. Self-acting gates are often used for this purpose. The gate being hinged below its centre, the pressure of the sewage on that portion of the gate which is below the hinge fixes it in position. As the sewage rises, the upper portion of the gate is likewise exposed to the pressure of the sewage, and presenting a larger area than the part below the hinge, a point is at length reached when the gate tilts, assuming a horizontal position, and the sewage escapes. Flushing gates are not used for flushing the upper ends of brick sewers, nor are they used for flushing pipe sewers. For these purposes, automatically discharging siphon flush tanks find a most useful application. They should be supplied with water from a tap connected with the town water mains, and regulated to discharge at intervals as required.

It might be thought that the pipe sewers used with the separate system do not require artificial flushing. But experience has taught otherwise, and it must be remembered also that under this system the sewers are not

flushed by storm waters. There can be no doubt that heavy rainfall is very effectual in flushing sewers ; but besides introducing a quantity of grit and sand from the roads, rainfall cannot be depended upon in this climate to occur at properly recurring intervals, and is often absent for long periods in summer, when sewer deposits are most abundant and most offensive.

The *ventilation of sewers* is a matter of importance, as the health of a sewered district probably depends to some extent on the efficiency of the sewer ventilation.

The investigations of Mr. Parry Laws and Dr. Andrewes on the micro-organisms of sewage and sewer air tend to show that sewer air has no power of taking up bacteria from the sewage with which it is in contact. They found that the micro-organisms present in sewer air are much more nearly related to those found in the outer atmosphere than to those existing in sewage. In the course of their experiments, the nature of the organisms in some 1,200 litres of sewer air was determined. Not once was the *Bacillus coli communis* found in such air, though the former is present in sewage in numbers varying from 20,000 to 200,000 per cubic centimetre. The authors conclude that the possibility of the existence of the bacillus of typhoid in the air of our sewers is infinitely remcte.

Mr. Parry Laws and Dr. Andrewes have also experimented on the vitality of the bacillus of typhoid in sewage. They conclude, as the result of their investigations, that sewage does not form a medium in which much, if any, growth of the bacilli is possible under natural conditions. The death of the bacilli in sewage is probably only a matter of a few days, or at most one or two weeks. But this degree of resistance may, nevertheless, be sufficient to allow of their being carried

in sewage to remote distances, and of their being able to produce disastrous results should they gain access to any water-supply.

These researches are very interesting, but the conclusions deduced are not altogether in harmony with practical experience, and cannot be at present accepted as authoritative on the harmlessness of sewer air, for experience teaches that many morbid conditions are induced, directly and indirectly, by exposure to drain and sewer gases. The following are the most generally recognised: Vomiting, gastro-enteritis and diarrhœa, faintness, headache, chronic blood-poisoning (irregular temperature, anorexia, headache, boils, sickness, septic arthritis, etc.), follicular tonsillitis, and diphtheritic throats.

Chemical examination shows that sewer air is subject to wide variations. A sample of air taken from a choked sewer in Paris was found by Parent Duchatelet to contain only 13·79 per cent. of oxygen, and as much as 2·99 per cent. of sulphuretted hydrogen. The air of closed cesspools in Paris must often have been quite as deficient in oxygen to have caused those symptoms of partial asphyxia from which the workmen employed to empty them occasionally suffered.

Where the quantity of sulphuretted hydrogen has been relatively great, sudden death has in some instances resulted amongst those who opened the cesspool. The same results have followed when men have entered sewers. Whenever it is necessary to enter an old or foul sewer (or cesspool) the following precautions should be taken: Open the lids of the two adjacent manholes and leave open for some time; then cautiously lower a lighted candle into the sewer, which must not be entered unless the candle burns brightly. If there is a likelihood of explosive gases being present in the sewer, a miner's

safety-lamp should be lowered, or a mouse in a cage; in the latter case, if the mouse is lively after ten minutes in the sewer, it will be safe for a man to enter it. Whenever circumstances appear to warrant it, the man should have a strong rope tied around his shoulders, so that he could be lifted by it by a comrade, who should always be in readiness; and if he should have to crawl along the sewer, a rope should also be securely tied to his ankles, so that he may be drawn back if overpowered by the gas.

In the London sewers the air is generally fairly pure. The most impure sample taken by Dr. Russell from the Paddington sewers was found to contain 0·51 vols. CO_2, 20·7 vols. O, and 78·79 vols. N in 100 vols. The most offensive gases are given off from sewers in which deposit forms, such as the old-fashioned brick conduits with flat bottoms, or oval sewers in which a portion of the invert has sunk below its proper level, or sewers which are too large for the volume of sewage they ordinarily convey, and in which the deposits and slime, formed on their floors and sides, are not removed by flushing. Outfall sewers in which sewage is, for any reason, backed up and stagnant during a portion of the day are also liable to become sewers of deposit. The deposit rapidly putrefies, giving off offensive gases, which escape through the nearest ventilator; or should the sewer be insufficiently ventilated, the foul gases find an exit through house drains and traps into the interior of houses.

In all sewers, owing to the constant variation of the flow of sewage through them, some deposit forms on their sides, which, being alternately wet and dry, rapidly putrefies, and parts with its putrefactive ferments to the sewage flowing by. In pipe sewers there is less tendency to deposit than in brick sewers of larger diameter, owing

to the smooth internal surfaces of the pipes, and to the greater frequency with which they are washed, as pipe sewers are more often running full or nearly full than brick sewers.

Natural ventilation of sewers, by which movements of air in them are produced, is due to a variety of causes, the most important of which are: (1) Where there is a strong and rapid stream, a current of air is produced which is in the same direction as the sewage stream, and of proportional velocity. Most of the openings into the sewers will be inlets for fresh air, drawn in by the current of air beneath, which finally escapes through the outfall sewer. (2) During the cold months of the year, the temperature inside a sewer is, owing to the warmth of the sewage, higher (average about 7° F.) than that of the external atmosphere, consequently the warmer sewer air tends to rise and to be replaced by the cold external air. During the warm months of the year the temperature of the sewer is by day often considerably cooler than the external air. In spring and autumn the temperatures inside and outside are more nearly equal. (3) The air of sewers is generally saturated with moisture, and therefore lighter as a rule than the general atmosphere outside. For this reason sewer air generally tends to rise up from any openings into the sewer. (4) The passage of hot liquids from houses and from factory boilers causes a rise in the temperature of the sewage and expansion of the sewer air. Blowing off steam from boilers into sewers causes a great rise of pressure, and unless ample ventilation is provided house traps will be forced. (5) During the early part of the day, the volume of sewage in the sewers increases rapidly to a maximum, and air is consequently slowly expelled, to be replaced by inflowing air as the level of the sewage falls. The rising

of the tide in an outfall sewer, not protected by a tidal valve, will also displace air, but the displacement is so gradual as to be almost inappreciable. Where storm waters are admitted into the sewers, sudden heavy rainfalls exert a marked influence in expelling air, which is somewhat counterbalanced by the aspirating effect produced by the flow of air in the direction of the current. (6) Sudden falls of barometrical pressure cause air and gases dissolved in the sewage to be given off. (7) Sudden variations in temperature of the external air produce variations in pressure of the sewer air. A high temperature favours decomposition of the sewage and evolution of gases.

Openings into the crowns of sewers from the surface of the roadway should be made at distances of not more than 100 yards apart. Some of these will act as inlets, and others as outlets, and the pressure of air in the sewer will at no time be able to rise sufficiently to force the traps on house pipes and drains.

There are objections which apply to the method of ventilating sewers by means of the soil pipe ventilators of houses, as when this method is carried out there must be no disconnecting traps to the house drains, and fresh-air inlets to the drains cannot be fixed. Sewer air escaping in large volumes near dormer windows might also cause a serious nuisance. Where a disconnecting trap is fixed on the house drain, a 4-inch pipe may be carried up to the ridge of the roof from the drain on the sewer side of the trap, its end being left open; and it will be found useful as an exit for sewer air when used in combination with road ventilators. But it is needful to bear in mind that where rain water is admitted to the sewers, during heavy rainfall, when ventilation is most required for affording a safe exit for suddenly displaced sewer air,

house drains, or any part of them, are often useless for this purpose, as their openings into the sewer may be sealed by the height at which the sewage is flowing in the sewer.

The best form of street ventilator is a shaft sunk from the middle of the roadway to the crown of the sewer. Beneath the grating at the surface of the street should be placed a dirt-box to catch gravel and mud, which would otherwise fall into the sewer, a space being left around the box for the passage of air. The dirt-box should be capable of removal from the surface of the road. Ventilators may also be constructed in connection with manholes. A shaft is sunk for a short distance by the side of the manhole, openings being made between them for the passage of air. Mud and gravel fall to the bottom of this shaft, from which a pipe conducts the water to the sewer beneath. The air which escapes from the sewers by these street ventilators is rapidly diluted with fresh air; and, from their position in the centre of the roadway, there is the least chance of offence to foot passengers or of foul air gaining entrance to houses. In narrow courts and streets, especially at the upper or dead ends of sewers, the surface ventilators should be replaced by shafts carried up from the crown of the sewer to above the tops of houses; for it is desirable to avoid any risk of foul sewer air collecting in stagnant courts and streets surrounded by buildings, in which rapid dilution of the sewer exhalations with fresh air might not always take place. Street gullies should be effectually trapped, both to prevent mud and sand entering the sewer, and to avoid an escape of sewer air close to the footways and the fronts of houses.

Iron wire baskets containing small wood charcoal were at one time extensively used to sweeten the air

escaping through the ventilators. When dry they exercise considerable influence in oxidizing and deodorizing organic vapours. But they rapidly become wet from rain and watery vapour, and then they are not only useless as deodorizers, but the pores are so clogged as to obstruct all passage of air through them. For these reasons their use has been nearly everywhere discontinued.

Various processes have from time to time been patented for deodorizing the sewer air escaping from street ventilators by passing it through chambers containing gases, generated by the automatic and gradual mixing of different chemical solutions. More recently a method of cremating the sewer air, by passing it over or through a gas flame, placed in a chamber at the top of the ventilator, has been tried. By this method the escaping sewer air is heated, possibly even to the point of sterilization, whilst the combustion of the gas tends to create an artificial draught up the sewer ventilator. There can be no question that any general adoption of such systems is undesirable. If they are successful in mitigating nuisance from sewer ventilators, they tend to conceal bad or defective conditions of the sewers themselves, which are primarily the cause of the escape of offensive gases, and which, therefore, should be remedied in the first instance. If, on the other hand, the sewers are well laid and self-cleansing, they are not required at all. Should the sewers be so old and dilapidated as to be generally offensive throughout a district, it would probably prove less expensive in the long-run, and far more beneficial to the public health, to reconstruct them on modern principles than to inaugurate a system of concealing the effects without attacking the cause.

Where sewers are laid with steep gradients, it is found that a current of air tends to pass in the reverse direc-

tion to the flow of the sewage from the low to the high levels. To prevent the escape of large volumes of foul air at the upper parts of a sewered district, it is necessary to construct at various points a tumbling-bay with manhole and ventilator opening above at the street-level. Then the sewer air in its course upwards meets the flap valve, hung from the crown of the sewer immediately over the tumbling-bay, and is forced to escape into the outer air through the ventilator.

It was at one time thought that by connecting sewers, by means of shafts, with a furnace chimney, a powerful extractive force, useful in ventilating a large portion of the system, would be put in operation. By this method, however, a great draught for a short distance only is produced, as air rushes in from all openings in the neighbourhood to supply the place of that extracted by the furnace. Beyond a very short distance no effect is produced, and there is besides considerable risk of traps in houses being drawn. If any such method is adopted, the chimney selected should be one in connection with a furnace which is kept going day and night throughout the entire year, and all openings into the sewers within the area it is desired to ventilate must be carefully closed. At the same time the connections of house drains to the sewers should be examined, to make certain that such an intercepting siphon trap exists on every drain as will not become unsealed. The method is really only applicable to large main sewers which do not receive house drains, but intercept the sewage from tributary sewers.

Adequate ventilation is just as necessary for pipe sewers as for brick sewers. The experience at Croydon is sufficient proof of this. Buchanan reported that "to some extent when sewers are running freely, but greatly more when they are not running freely, displace-

ment of air from them is an affair of sewer calibre." Displacement of air from the entry of a volume of water will be sixteen times greater in a 6-inch sewer than in a 2-foot sewer, and the displacement will be greatly more sudden. "Hence the air in a small sewer is liable to be under far greater pressure than the air in a large sewer." Numerous openings into the outer air must exist for the exit of this displaced air, or it will find its way into houses through trapped and untrapped pipes.

Outfall Sewers.—In some cases it may be necessary to carry the sewage of a town across a river or a valley. This may sometimes be done by bridging; but usually the outfall sewer is at too low a level to permit of it. In such cases the sewer should be carried across by means of an inverted siphon, formed of wrought-iron pipes with riveted flange joints, laid in the bed of the river or valley. Arrangements must be made for preventing the accumulation of solid matters at the lowest point of the siphon, resulting eventually in a stoppage, to which there is a tendency, unless the current through is of sufficient velocity to carry all solid matters with it. With this view the sewage may be strained before passing through the siphon, or the siphon must be periodically flushed. To give exit to air under pressure in the siphon, which might prevent its proper action, a ventilating pipe should be attached to the descending arm.

The Disposal of Sewage.

The disposal of the sewage of a town or district is usually the most difficult problem to solve of any connected with the sewage question. Fortunately, since the Rivers Pollution Prevention Act became law in 1876, the nature of the problem has been altered. The

question for a local authority to determine is now, not how to get rid of its crude sewage with the least trouble and expense, but how to purify the crude sewage so that it may be admissible into a stream. For the Rivers Pollution Prevention Act made it illegal to discharge crude sewage into a *stream*, this term including rivers, streams, canals, lakes, and watercourses, other than watercourses mainly used as sewers, and also the sea to such extent, and tidal waters to such point, as may after local inquiry, or on sanitary grounds, be determined by the Local Government Board. It is greatly to be regretted that this Act has in many parts of the country entirely failed to prevent the continued pollution of streams, by which the community has already so largely suffered. The interests involved in the continuance of the existing state of things were, and are, too great to be set aside to benefit merely the health and comfort of the people. The crude sewage and waste refuse of many of our Northern manufacturing towns still pollute the streams and rivers as in former years.

The evils that result from the discharge of crude sewage into the estuaries of rivers, were exemplified in the case of the discharge of the crude Metropolitan sewage into the Thames at Barking and Crossness. It is true that in this case the volume of sewage discharged is enormous—about 150,000,000 gallons daily—and it has even been calculated that, during very dry weather, the sewage in the neighbourhood of the outfalls formed one-sixth of the whole volume of the river water. But even if the volume of sewage were very much less, there are certain circumstances in connection with tidal rivers which are adverse to or retard that process of self-purification by dilution and oxidation, by which only can a nuisance and danger to health be overcome.

Where sewage is discharged into fresh running water and at once largely diluted, it becomes in course of time to a great extent purified. Distributed through a large volume of clean water, the organic matters are oxidized through the aid of nitrifying bacteria by the oxygen dissolved in the water, and by that given out by minute water plants (algæ, diatoms, and desmids), and are also assimilated by minute animals (infusoria, rhizopoda, entomostraca, anguillulæ, etc.). They are thus purified, or got rid of, without the occurrence of putrefaction and the formation of offensive gases, which must occur when the sewage is not sufficiently diluted with fresh water and the temperature of the air is high, the growth of bacterial organisms then taking place to such an extent as to cause putrefaction. Putrefactive bacteria will no doubt in time break up complex organic matters into their constituent parts, and thus purify sewage; but the process is one productive of nuisance and injury until the ultimate effect is attained.

In the case of tidal rivers, the Reports of the Royal Commission on Metropolitan Sewage Discharge show that there may be a considerable concentration of sewage in the river, forming what has been termed a "sewage zone," due to the oscillation of the tides: for the river water into which the sewage is discharged is not pure water, but is water that by reason of the tidal oscillations has already become contaminated by the accumulations of successive previous sewage discharges. The only true sources of dilution are the land water entering from above, and the sea water from the mouth of the river. During dry weather, when the quantity of land water is slight, the displacement of the sewage towards the sea is very slow (about a quarter of a mile daily in the case of the Metropolitan sewage); so that the sewage discharged on

any particular day oscillates up and down the river with the tide, and is continually receiving fresh increments. The sewage, too, that is discharged after high-water on an ebbing tide will be carried up by the flowing tide above the outfall; and when neap tides are giving place to spring tides, the whole volume of discharged sewage is carried up higher and higher above the outfalls every day as the spring tides increase. The consequence is that at such times the sewage may be carried in the river up to or above the town so discharging its sewage.

The effect, too, of the sea salts in estuary water is to cause a precipitation of organic matters and a deposit of mud, whilst the oxidation and purification processes are delayed by their presence.

To estimate the relative volumes of fresh water and sea water, in a tidal river, it is necessary to determine the quantity of chlorine in the tidal water. Sea water contains 1975 parts of chlorine per 100,000, and the quantity of chlorine in the fresh water may be considered a negligible quantity.

Example: If the amount of chlorine in a tidal water is 200 grains per gallon, in what percentages are the fresh and sea water mixed?

200 grains per gallon $= 200 \times \frac{10}{7} = 285{\cdot}7$ parts per 100,000.

Let $x =$ proportion of sea water in 100,000 parts of tidal water then

$$\frac{x}{100{,}000} = \frac{285{\cdot}7}{1975}$$

$$x = \frac{100{,}000 \times 285{\cdot}7}{1975} = 14{,}466.$$

That is to say, in 100,000 parts of tidal water, 14,466 parts are sea water, and 85,534 parts are fresh water; or sea water forms 14·47 per cent., and fresh water 85·53 per cent., of the tidal water.

This calculation is an important one for sewage precipitation works on the banks of tidal waters, as when the chlorine is relatively high in amount, and the quantity

of land or fresh water coming down is consequently small, a larger quantity of chemicals must be used in order to obtain an effluent of sufficient purity to counteract the tendency of the excess of sea salts in the tidal water to precipitate the organic matters in the effluent, and so cause a deposit of sewage mud.

If the volume of sewage discharged is relatively small to the volume of water in the river, the sewage will in time be purified; but such water can under no circumstances be a proper source of supply for drinking water. If the relative proportions of sewage and river water are the same, the non-tidal river possesses great advantages over the tidal; for the sewage is at once carried away, and cannot return above the outfall, whilst the purifying processes are not hampered by the presence of sea water.

Under certain circumstances sewage may be discharged into the sea without risk of nuisance and offence. If the sewage can at all times be borne away from the shore out to sea, it becomes mixed with an immense volume of water and rendered harmless. The danger is, lest sewage should be cast up by the tide on the foreshore, or borne along by currents the whole length of the sea-front of a town. To avoid such an event, the outfall must be chosen at such a spot that the sewage, at whatever state of the tide it may be discharged, shall be carried by currents, where such exist, straight out to sea, or at least in a direction away from the town.

The outfall sewer must open below the level of the water at all states of the tide, and its mouth should be protected by a tidal valve to prevent sea water entering it. The prevailing winds should also be studied, to prevent the possibility of floating fæcal matters being blown back on to the beach. If the town lies at a low level, so that its sewers are tide-locked for several hours of each

tide, tanks must be constructed to retain the sewage which accumulates at such periods; or a certain length of oval tank sewer must be built for the same purpose.

Tank sewers, however, are very generally productive of nuisance. The tide-locked sewage stagnates in them, and a copious deposit of sediment takes place which gives rise to the formation of foul gases. In such cases no amount of ventilation suffices to obviate the nuisance. It is better to have recourse to steam pumping at the outfall, or to use Shone's Pneumatic Sewage Ejectors to relieve the sewers of their accumulated sewage.

In Shone's system the motive power is compressed air, which is conveyed from a central station by wrought-iron pipes to the cylindrical reservoirs or "ejectors," which are situated in chambers beneath the streets at different parts of the town, and receive the sewage from the street sewers. When the ejectors are full, a valve is opened and compressed air is admitted by means of a float acting on a counterpoised lever, and the sewage is thereby forced out into a gravitating sewer at a higher level. A ball valve in the pipe sewer entering the "ejector" prevents the sewage from being forced backwards by the compressed air; and as the sewage is discharged and its level sinks in the "ejector," the sinking of the float closes the valve of the compressed-air tube, and a fresh charge of sewage can then enter. The great advantage of the system is that good gradients can be given to the sewers, for the ejectors are placed at depths below the surface of the ground sufficient to permit of house drains and street sewers, with which they are connected, having a good fall, and the sewage is carried away and forced out of the town in a fresh condition. In addition, no storage is required as in ordinary pumping, for the rate of working of the ejectors varies with the rate of flow of the sewage

into them, although the air-compression machinery at the central station works nearly uniformly. Shone's system is now in operation at several towns lying on low flat ground, and has been found very beneficial in preventing the evils which result from absence of proper sewer gradients.

Lierner's pneumatic system of sewage removal and treatment is carried out at Amsterdam and Trouville. It is claimed to be especially applicable in towns where the water-supply is limited, and where the ground is too flat to admit of good sewer gradients. There is an air-tight system of sewers, the contents of which are frequently emptied into closed chambers fixed in different parts of the town, by means of a powerful air-pump at a central station. From these chambers the sewage is sucked into a steam concentrator at the central station, and is there heated to about 100° C., after the ammonia has been fixed by the addition of sulphuric acid. The dried sludge ("poudrette") finds a ready market as manure. It appears that the pipes tend to get clogged, but otherwise the system works well.

The Purification and Utilization of Sewage.

It can safely be said that in this country no stream or river should ever receive crude sewage; for so numerous are the towns on the banks of nearly every stream, that, although the sewage of one town might be purified after a certain run, it would be quite impossible for any stream to purify the successive sewage discharges from every town on its banks. As the sewage must be purified before discharge, the question arises whether it can at the same time be utilized, and made to pay the whole or part of the expenses incurred in its purification. It becomes

necessary, then, to consider the amount and value of the manurial ingredients contained in ordinary town sewage.

In the first place as to the chemical composition of sewage. The Rivers Pollution Commissioners give as the average in water-closeted towns, in 100,000 parts, 72·2 of total solid matters in solution, in which there are 4·696 parts of organic carbon ; 2·205 of organic nitrogen ; 6·703 of ammonia ; total combined nitrogen 7·728 ; chlorine 10·66 ; and an inappreciable quantity of nitrogen as nitrates and nitrites. In 100,000 parts there are, besides, 44·69 of suspended matters, of which 20·51 are organic, and 24·18 mineral matters. This is an average from a large number of analyses ; but it must be borne in mind that the sewage of different towns varies greatly in character, and that the sewage of the same town varies in strength from day to day and from hour to hour. To obtain an exact knowledge of the average strength of a day's sewage in any town, samples must be taken frequently—at least every hour—and to form a sample for analysis they must be mixed in such proportions as are indicated by gauging the flow of sewage at the time each sample was taken. In this way only can the average composition of the sewage be arrived at with anything like exactitude.

The strength of the sewage depends on the number of water-closets in the town (proportion of water-closets to middens), the amount of water-supply per head of the population, the amount of waste liquors discharged into the sewers from manufactories, and, in the case of drain sewers, the amount of rain that has fallen, and of subsoil water that has found its way into them. During the early part of the day (in dry weather) the sewage of any town is strongest, and the flow greatest, whilst at night the sewers may be discharging nothing but subsoil water.

The chief valuable ingredients of sewage are the different forms of combined nitrogen, the phosphates, and salts of potash. The money value of these constituents in 100 tons of the sewage of the strength noted above is 17s., the dissolved matters being worth 15s., the suspended 2s. This gives a value to the sewage of about 2d. per ton. We have already seen that the yearly excretal refuse of an individual of a mixed population is worth from 6s. 8d. to 7s. (see p. 87), and this refuse, if diluted with water to form 40 tons of sewage (an average dilution of 24 gallons per head per day), will also give a value to the sewage of 2d. per ton. This dilution is about that of the London sewage during dry weather. It may further be stated that 855 tons of the sewage of the composition given by the Rivers Pollution Commissioners contain 1 ton of solid matters (in solution and in suspension), estimated to be worth £7 5s. 4d. From such data as these calculations might be made of the total yearly value of the sewage of any town. But such theoretical calculations may be very far from representing the real practical value.

The composition of sewage from midden towns (see p. 88) does not differ very materially from that of water-closeted towns. The Rivers Pollution Commissioners gave as the average composition of midden town sewage in 100,000 parts: Total solids in solution 82·4; organic carbon 4·181; organic nitrogen 1·975; ammonia 5·435; nitrogen as nitrates 0; total combined nitrogen 6·451; chlorine 11·54; total solids in suspension 39·11, of which 21·30 are organic matters, and 17·81 mineral matters.

Subsidence, Straining, and Precipitation.

By allowing sewage to settle in tanks, a portion of the suspended matters subsides to the bottom, and a more

or less clarified liquid can be decanted from the top. By straining crude sewage through beds of ashes or charcoal, the suspended matters are removed; but the filters speedily become clogged, and require frequent renewal at great expense.

Certain chemical substances, when mixed with sewage prior to its entering settling tanks, cause a more rapid and copious precipitation of the suspended matters than can be effected by subsidence alone. The number of chemicals that have been used or advocated for this purpose is enormous, as may be seen on inspection of the specifications of patents taken out to protect the inventors of such processes. Only three substances are now in common use as chemical precipitation agents, the others having either proved worthless or too expensive for general use. Lime—as lime-water or milk of lime—sulphate of alumina, and protosulphate of iron, are the substances now most commonly used as precipitation agents, either singly or in combination.

The precipitating effect of lime on sewage is due partly to its combination with carbonic acid, forming an insoluble carbonate of lime, and partly to its combination with some of the organic bases of sewage. These substances subside, carrying with them most of the suspended matters in the sewage, and sink to the bottom of the tank, forming the sludge; whilst a more or less clear liquid, the effluent, remains above. If too much lime is added, the sludge and effluent, being strongly alkaline, tend soon to undergo decomposition. The proportion of lime most usually added to sewage of average strength is 15 grains to the gallon of sewage for milk of lime (lime slaked with water), and from 5 to 10 grains to the gallon for lime-water (lime dissolved in water).

The precipitating effect of sulphate of alumina on

sewage is due to combination of the sulphuric acid with lime and other bases in the sewage, whilst the alumina hydrate is precipitated in a flocculent condition, entangling and carrying down in its course most of the suspended organic matters. The crude sulphate of alumina used as a precipitant is acid, and reduces somewhat the alkalinity of the lime which is employed along with it. Many authorities recommend the use of lime with sulphate of alumina for precipitating sewage. For treating sewage of medium strength the quantities need not exceed 5 grains of lime and 5 grains of sulphate of alumina per gallon of sewage.

When protosulphate of iron is added to alkaline sewage or to sewage which has been already treated with lime, a highly flocculent hydrated protoxide of iron is formed, which falls to the bottom of the tank, carrying suspended organic matters with it. The iron salt is also a powerful antiseptic, checking further putrefaction of the sludge and effluent, when used in sufficient quantity. But its use is attended with the disadvantage that the mud banks of the stream, into which the effluent is discharged, are blackened by the formation of sulphide of iron—a somewhat sentimental disadvantage, but a very real one. When used with lime, protosulphate of iron should be added in the proportion of from 2 to 5 grains per gallon of sewage. The London sewage is thus treated, the lime and iron being added in the proportion of 5 and 2 grains to the gallon of sewage respectively.

The combination of iron with alumina is also effective as a precipitating agent, and both enter into the composition of the two well-known sewage precipitants—Ferrozone and Alumino-ferric.

These three precipitating agents—lime, sulphate of alumina, and protosulphate of iron—cause a more or less

complete deposition of the suspended matters in sewage, and thereby remove the grosser sewage odour from the effluent; but they have very little, if any, effect in removing from the sewage the organic matters in solution. Sulphate of alumina is said to have the effect of removing 5 per cent. of the dissolved organic matters of sewage, but lime and iron remove practically none. It follows, then, that the matters precipitated from sewage, which form the sludge at the bottom of the tanks, are comparatively worthless, whilst the bulk of the valuable manurial ingredients remains in the effluent.

To insure the most complete clarification of the sewage liquid by chemical precipitants, the following conditions must be satisfied: The sewage must be fresh and undecomposed, and the larger solid bodies should be strained from it before the admixture of the chemical precipitants. The chemicals must be added to the sewage immediately before it arrives at the tanks, and must be well stirred and mixed up with it by means of rotatory beaters. There must be sufficient tank accommodation. The tanks are often arranged in series, so that the sewage may pass slowly but continuously through two, three, or four tanks before the effluent escapes into the effluent channel, which should be of considerable length and kept scrupulously clean. The tanks must be at least 4 feet deep, and the effluent passing out should flow over a weir not more than ½ inch below the surface into the next tank of the series, or into the effluent channel. After a certain period of continuous working, the flow of sewage through the series must be discontinued, and the sludge allowed to settle, the clear liquid above being drawn off through float valves into the effluent channel. There should be

a double set of tanks, in order that the treatment of the sewage may continue, whilst the sludge is being removed. The sludge must be frequently removed or it will putrefy, and black masses will be disengaged, which, rising to the surface, give off foul gases. The tanks, when emptied, must be thoroughly cleansed before being refilled.

Occasionally substances, which act as deodorants or antiseptics, are added to the sewage as well as the chemical precipitants. Amongst these we may mention black-ash waste (Hanson's process), used in conjunction with lime. Black-ash waste is prepared from the refuse of alkali works, and contains hyposulphites and sulphites of lime, which are powerful reducing or deoxidizing agents. Black-ash waste has considerable deodorant and antiseptic properties, and has proved of service in mitigating the pollution of the river Lea—the sewage of both Tottenham and Leyton being now treated by Hanson's process. The addition of manganate of soda and sulphuric acid to chemically treated sewage has been recommended by Mr. Dibdin in order to promote oxidation.

Another deodorizing method is that known as the Amines process. The sewage is treated with milk of lime and with a small quantity of herring brine, which contains a certain percentage of the compound ammonia termed methylamine. This substance acts as a deodorant and antiseptic, and is said to completely sterilize the effluent, so that it undergoes no secondary fermentation; whilst the sludge is so far deodorized that it can be dried in pits exposed to the air, or on the floor of a drying kiln, without giving rise to noxious effluvia. It is now generally recognised that the use of deodorants, as auxiliaries to precipitation processes, is advantageous, if they do not

interfere with the natural agencies of purification. Black-ash waste and herring brine appear to comply with these conditions.

In the Hermite system, sewage is treated with partially electrolyzed sea water. The electric current, generated by a dynamo, which is driven by a steam-engine, is passed through the sea water contained in a galvanized iron tank, between electrodes of zinc and platinum. In doing so, magnesium chloride is probably decomposed, forming a disinfecting fluid of a strength equal to 0·75 gram of chlorine per litre. The active principle of the fluid may be an oxygenated compound of chlorine, hypochlorous acid, or hypochlorite of magnesia. Dr. Kelly says the solution has the smell of a weak solution of bleaching-powder, and the strength of the solution is from fifty to sixty times weaker than a saturated solution of good bleaching-powder. It contains no free chlorine. It is claimed for the process by its inventor that the solution produces an instantaneous decomposition of fæcal matter in sewage, and effectually sterilizes the sewage, but the experiments conducted at Worthing do not bear out these assertions. A solution of bleaching-powder in water would probably be equally effectual, and much cheaper.

In the A B C process now carried on at Aylesbury and at Kingston-on-Thames by the Native Guano Company, alum, blood, clay, and animal and vegetable charcoal are added to the sewage. The blood is said to act as a refiner, but in the small quantities used its action is probably nil; the clay acts as a weighting material, carrying down the precipitated matters; whilst the charcoal acts to a certain extent as a deodorant. A highly clarified effluent is produced by this process on a small area of ground, and the dried sludge ("poudrette"

or "native guano") is said to find a ready market at £3 a ton.

The suspended matters, or sludge, of sewage being deposited at the bottom of the settling tanks, the questions arise: What is to be done with the clarified effluent? and, How is the sludge to be got rid of? No nuisance will result if the effluent is discharged into a quickly-running stream or river, whose volume is at least ten times greater than that of the effluent, and which is not used below the point of discharge as a source of supply of drinking water. The danger is lest, during drought in summer, the volume of fresh water might considerably diminish; and then, the effluent sewage not being sufficiently diluted, would putrefy and become turbid, forming foul deposits in the bed of the stream, and giving rise to offensive exhalations. This would be especially likely to happen if, at the same time, the temperature of the air was high. By this method, too, all the valuable manurial ingredients of sewage run to waste. The only satisfactory mode of purifying the effluent sewage is to carry it over land by irrigation, or through specially constructed filter-beds.

Where it is not possible to obtain land for this purpose, the partial purification of the effluent from the tanks may be effected by passing it through specially constructed filters, consisting of burnt ballast, coke, coke-breeze, coal, gravel, or fine sand laid upon magnetic oxide and carbide of iron (polarite). The nitrifying organisms in the pores of the filter exert a powerful oxidizing effect on the organic matters dissolved in the effluent, by which these are converted into nitrates and nitrites, etc. The slower the filtration, *i.e.*, the longer the effluent liquid is in contact with the particles com-

posing the filter-bed, the greater is the purification. The filtration must be intermittent to allow of aeration of the filter.

The sludge left at the bottom of the tanks is generally conducted into a well, and thence pumped out in a semi-liquid condition. It contains from 90 to 95 per cent. of water. It may be got rid of by allowing it to flow, or forcing it up, in this liquid condition, along raised carriers on to land, into which it is subsequently dug, thereby eventually becoming incorporated with the soil. This is the method pursued at Birmingham, the sewage being treated with lime, and the effluent from the tanks being purified by irrigation over the soil of the sewage farm. If the semi-liquid sludge is allowed to dry by exposure to the air in pits, it invariably causes a nuisance, so that it is the usual practice to press part of the moisture out of the sludge by hydraulic filter presses, by which a solid cake, containing from 50 to 60 per cent. of moisture, is produced. The pressed sludge can be stored up without causing any nuisance, and sold or given away according to the demand for such sewage manure. It may be further dried by heating in drying machines, and then ground into a granular condition, containing from 20 to 30 per cent. of moisture. In this condition the manure is far more suitable for application to land than in the form of the coherent masses which issue from the filter presses.

To calculate the weight of sludge cake formed from a given quantity of sludge taken from the tanks, Professor Robinson has devised the following formula:

Let W = weight of sludge from the tanks.
,, P = percentage of moisture remaining in the pressed sludge.
,, X = weight of sludge cake.

Then $X = \dfrac{10\,W}{100 - P}$

The average composition of pressed sludge cake from the Metropolitan sewage Mr. Dibdin states to be: Moisture, 58 per cent.; organic matter, 16·7 per cent.; mineral matter, 25·25 per cent.; ammonia, 1 per cent.; phosphate of lime, 1·44 per cent. The value of a ton of this sludge cake, calculating ammonia as worth 7d. per pound, is about 17s. This value corresponds with that obtained by calculating the suspended matters in 100 tons of sewage as being worth 2s. For the suspended matters from about 850 tons of sewage will be required to produce a ton of sludge cake containing from 50 to 60 per cent. of moisture. This is the theoretical value: the price obtained from the sale of this sludge cake varies in different towns; in some there is no demand for it, and it is either burnt in a destructor furnace, used for raising low-lying grounds, or even a small premium is paid to farmers for removing it.

Calculation.—State approximately the amount of moist sludge containing 90 per cent. of moisture that can be precipitated daily from the sewage of a population of 10,000, with a water-supply of 20 gallons per head per day.

The sewage may be taken as equivalent to the water-supply, viz., $20 \times 10{,}000 = 200.000$ gallons per day; or $10 \times 200{,}000$ lb. by weight $= \frac{2{,}000{,}000}{2{,}240} = 892·86$ tons. We will suppose that in every 100,000 parts of the sewage 40 parts of suspended matter can be precipitated by chemical reagents. Then the dry solids precipitated from the sewage amount to $\frac{40}{100{,}000} \times 892·86$ tons $= 0·357$ ton, and the moist sludge containing 90 per cent. of moisture will be $10 \times 0·357 = 3·57$ tons.

The Biological Purification of Sewage.

The chief natural agencies concerned in the purification of organic matter are micro-organisms. It is almost entirely due to these beneficent organisms that organic

matter—whether it be fæces deposited on the surface of soil, or an animal body buried within it—eventually becomes resolved into invisible and harmless gases and mineral ash. Sterilized organic matter remains undecomposed for indefinite periods.

Ever since cesspools were employed for the reception of the sewage of a house, it has been noted that the material which is periodically emptied out of the cesspool, or which overflows from it, is a liquid containing very little solid matter suspended in it. The cesspool must be almost entirely emptied before a perceptible deposit of solid matter is encountered. How is it that a comparatively small cesspool, with an overflow discharging nothing but liquid material for a year or more, does not become filled with the large amount of solid fæcal matter daily entering it? The answer is that micro-organisms in countless myriads are constantly feeding upon this solid matter, causing its liquefaction into products which ultimately become dissolved in the liquid part of the sewage. The organisms which effect this change are of many forms, and may be broadly classified into three groups:

1. Those which work in the absence of oxygen (anaerobes).

2. Those which work in the presence of oxygen (aerobes).

3. Those which are capable of working either in the presence or absence of oxygen (facultative aerobes).

Our knowledge of the last-named group is not sufficient to enable us to speak with certainty as to the part they play in sewage purification, but it is certain that both the aerobes and anaerobes are concerned in the final resolution of organic matter. With regard to these two classes of organisms, there are reasons for believing that the

anaerobes are the most efficacious in causing the liquefaction of the solid matter contained in the sewage of cesspools. Prior to attack by these liquefying organisms, the solid organic matter is in a more or less stable condition; but as the result of their life action the complex organic molecule is split up into by-products, which are largely soluble and unstable, and considerable quantities of gases (CH_4, NH_3, CO_2, and SH_2) are evolved.

This *first stage of purification* is closely analogous to the process of gastric digestion, whereby the organic matter is split up and liquefied, the gelatinous and albuminoid material undergoing a peptonizing process, and the non-nitrogenous substances being reduced, and finally converted into CO_2 and H_2O. As in digestion, also, the element of time is essential. The organisms must not, therefore, be overfed, or asked to do their work in too short a time, or their activity will be checked.

The *second stage of purification* is doubtless largely performed by the aerobes, and, in consequence, every effort should be made to set them their work under conditions favouring an abundant supply of available oxygen. The more or less stable solid organic matters having been broken up, rendered less stable, and thrown into solution in the first stage, are in the second stage converted into the ultimate products CO_2, NH_3, H_2O, and traces of SH_2; nothing ultimately remaining but a trivial quantity of mineral matter, rich in nitrates, chlorides, and sulphates.

Now, it is only very recently that anyone has proposed to utilize these natural agencies of purification in the disposal of sewage in bulk, but we have already arrived at such a stage of knowledge that it may safely be claimed that success is assured. The advantages to be gained over the older, or what may be termed the chemico-biological method (in which the sewage solids are first

precipitated by chemicals, the comparatively clear effluent being then exposed to biological agencies in filter-beds or in land) are obvious.

The almost useless sludge which resulted from the chemical treatment, the collection and ultimate disposal of which entails considerable labour and expense, is done away with, and the cost of the chemicals and of their application is also saved. But the greatest gain is doubtless in the direction of greater efficiency of treatment, which results in a purer and sweeter effluent—one more readily susceptible to the agencies of ultimate purification, and more valuable to vegetable life and less harmful to animal life.

We may now review the various means which have been adopted for utilizing these natural agencies in sewage purification. The first practical attempt to solve the problem was commenced by the Massachusetts Board of Health in 1888. The extensive experiments since made by that Board have established the fact that intermittent downward filtration through prepared filters of suitable material will, by reproducing the most favourable conditions of land filtration, achieve all the good results of the latter on a much smaller area. The experiment showed that the beds need not be of a greater depth than 4 to 5 feet, in order to treat satisfactorily 100,000 gallons of sewage to the superficial acre per diem. In such beds, after a week or two of sewage treatment, the particles of filtering material become covered with thin films ("colonies") of micro-organisms.

Mr. Scott-Moncrieff was the first (1891) to suggest a mode of treatment whereby the preliminary liquefaction of solid matters was brought about in a separate apparatus, and the purification of the matter in solution was subsequently effected. This mode of treatment of

sewage by separating the stages of its purification is doubtless advantageous, seeing that the classes of organisms concerned in the preliminary liquefaction are distinct from those concerned in the subsequent purification, and each class exerts its powers most effectually when kept apart from the other. There is, moreover, evidence that the second stage of purification itself comprises many subsidiary stages, and that special classes of organisms are concerned in these several stages.

Almost all the installations at present in use embody the principle of dividing, to a greater or less degree, the whole process of sewage purification by Nature's means into these two stages; Stage I. providing essentially for liquefaction of solids, and Stage II. for subsequent purification of the unstable and liquid products of Stage I.

The installation adopted by Mr. Scott-Moncrieff consists of two or more open tanks filled with large stones ("cultivation tanks"). The sewage is allowed to flow slowly and continuously into the false bottom of the tanks and to escape at the top. In its upward passage over the stones the solid matters of the sewage are retained, and the stones become coated with anaerobic liquefying organisms deposited from the sewage. Under the influence of these organisms the solids of the sewage become liquefied to such an extent that the effluent escaping from the top of the tank contains practically no suspended matter at all. In Stage II. of purification the aim is to bring the sewage under the most favourable aerobic conditions obtainable. To this end the tank effluent is conducted into a series of channels ("nitrification channels") freely exposed to the air and filled with large stones, which serve the double purpose of breaking up the current of liquid and thereby helping to thoroughly aerate it, and also of affording surfaces

on which the aerobic organisms can plant themselves in great numbers.

More recently Mr. Scott-Moncrieff has designed means of securing an even more complete aeration of the effluent from the tank, by the use of a series of trays containing filtering media, placed at intervals of a few inches one above another, so that the liquefied sewage delivered over the surface of the top tray is slowly sprinkled down in a descending series from tray to tray to the ultimate out-fall in the effluent collecting channel.

He also advocates, where possible, the addition to the effluent from the trays of a certain volume of well-oxygenated water.

Kenwood and Butler found from an extensive series of experiments performed upon an installation of a modified Scott-Moncrieff tank at Finchley, that the functions of No. 1 upward filter tank may be summarized as—

1. A straining off of suspended matter.

2. Dealing with this suspended matter so as not to allow it to accumulate unduly in the filter.

3. A partial purification of the sewage.

There was a continuous reduction of the more stable organic matter to unstable organic compounds, and subsequently of these unstable compounds to the ultimate products of anaerobic organic decomposition.

A microscopical examination of the retained matter disclosed the presence of an abundant fine granular débris which was rich in iron, particles of silica and carbon, algoid growths (some with chlorophyll and others without), a few live protozoa (rotifers mainly), vegetable hairs, bundles of vegetable fibres, large numbers of vegetable spiral vessels, zoogl\u0153a, an ovum of tænia, a few striated muscle fibres, cotton fibres, and human hairs.

By reproducing the conditions of a septic tank, or

hollow chamber, on a small scale, they found that the same changes which occurred in Scott-Moncrieff's stone filter tank took place in a hollow septic tank, only more slowly and with somewhat less tendency to continuously progressive purification.

Extensive experiments by Mr. Dibdin from 1891 to 1895 with the Metropolitan sewage led to his advocacy of what is known as the Sutton system of biological purification. The sewage is first strained of large particles by means of fine metal strainers introduced at the sewer outfall, where the sewage enters the works; it is then exposed to downward filtration through coarse beds. It is in these coarse beds that liquefaction should take place. They are 4 feet deep, and made of coarse burnt ballast of particles of such a size that they will pass through a 2-inch ring, but are rejected by a $\frac{1}{2}$-inch mesh; the object of using such coarse material being to admit the solid particles of crude sewage into the body of the bed, and also to favour thorough aeration when the liquid sewage is drawn off. The coarse material, moreover, does not get so readily clogged. The effluent from the coarse bed is then conveyed on to the surface of a fine filter 4 feet deep, constructed of particles which will pass a $\frac{1}{4}$-inch mesh, but which are rejected by one of $\frac{1}{16}$ inch.

The sewage is allowed to fill the beds almost to their top surfaces, and then to rest in them for a period of two hours, when the beds are slowly emptied and allowed to remain at rest for several hours, so that several of such filters are necessary in even a small installation. Each filter-bed is filled up thrice daily. This intermittent application of the sewage insures also a certain amount of aeration of the beds. One drawback to the use of the coarse or "roughing" filter is the fact that the upper stratum of the filtering material becomes clogged at in-

tervals with a black deposit of solid matter. The surface of such filters, therefore, requires occasional raking or ploughing.

The "septic tank" method was devised by Mr. Cameron of Exeter at about the same time that Mr. Dibdin's experiments were in progress.

The method, like that of Mr. Scott-Moncrieff, provides for a well-defined line of demarcation between the stages of liquefaction and of subsequent purification. Provision is made for liquefaction under strictly anaerobic conditions in a large covered receptacle provided with an inlet for the sewage and an outlet for the tank effluent. The sewage travels so slowly through the tank that every particle takes some twenty-four hours in passing through it. This period of time is sufficient for so complete a sedimentation and liquefaction of solids to be effected that the tank effluent contains but a few grains per gallon of fine suspended matter. The black deposit which settles in the bottom of the tank was found after fifteen months' working to be under 2 feet in depth. This deposit consists of indigestible material, and includes mineral matter, cellulose, vegetable and elastic fibres, cartilage cells, etc. The gases given off from the tank are not offensive, but are highly inflammable. The mixture of gases contains (Rideal) $CO_2 = 0{\cdot}6$, methane $= 24{\cdot}4$, hydrogen $= 36{\cdot}4$, nitrogen $= 38{\cdot}6$, in 100 parts.

The second stage of purification is effected by passing the dark-coloured tank effluent through an "aerator"—a long trough over the edges of which the liquid falls in thin films, thereby mechanically entangling a certain quantity of air; and from thence on to a series of coke breeze filters $4\frac{1}{2}$ feet deep. These filters are filled, rested while full, slowly emptied, and rested for many hours while empty in the manner advocated by Mr. Dibdin.

The effluent from the tank is applied to the filters in rotation by an ingenious automatic arrangement which removes the necessity for continuous manual attention. The practice at Exeter leads to about six hours being consumed in the filling of each filter, which then remains full for six hours; the filter is then emptied in half an hour, and is allowed to remain at rest for the remainder of the twenty-four hours (*i.e.*, eleven and a half hours). A fifth filter is kept in reserve, so that each filter gets a week's rest every month. The process has dealt efficiently with the sewage of some 2,000 of the inhabitants of Exeter, the filtered effluent collected by drains laid on the floor of the filter-bed being quite satisfactory. The Local Government Board has sanctioned a scheme for the treatment of the whole of the Exeter sewage on similar lines.

In Colonel Ducat's method the stages of liquefaction and subsequent purification go on continuously side by side in the same apparatus. A filter, some 8 feet in depth and varying in area with the amount of sewage it is required to treat, is built up from the ground-level with walls composed of agricultural drain pipes arranged so that their long axes are directed (with a slight fall) towards the interior of the filter. By this arrangement the wind, from whatever direction, can blow into the body of the filter, whereas the slope of the pipes prevents the sewage from flowing out of them. The body of the filter is formed of layers of coke, large at the top and small below, each layer, which is about 18 inches deep, being separated from its neighbours by an aerating layer of big stones and of pipes. Distributing troughs apply the sewage evenly over the top of the filter, which it slowly passes through, the effluent finally collecting in a channel which surrounds the bottom of the filter.

Colonel Ducat has also devised means of warming his filter in the winter, thus providing against the effects of frost, and also insuring a constant temperature specially favourable to the work of the organisms.

This process may furnish satisfactory results when dealing with town sewage, in which the stability of the organic matter has already been shaken by its sojourn in a sewer; but it is difficult to believe that the result could continue uniformly favourable where the sewage to be dealt with is essentially fresh in character, seeing that, the process being one of continuous action, the essential and all-important element of time is not provided for the "digestion," which must form the preliminary stage of sewage treatment.

General Remarks on the Biological Purification.

When any installation is provided for the natural purification of sewage, the organisms concerned in the process are planted on the filters, etc., by means of the sewage itself; but it is not until after the sewage has been applied to the installation for many days that the organisms have become sufficiently developed and differentiated to produce their best effects on the sewage as it passes through the installation.

In installations of the "septic tank" or the Scott-Moncrieff tank the provision made must be sufficient to hold at least one day's sewage flow. The matter is, however, complicated by the necessity of making provision for some at least of the storm water, which may at times swell the dry-weather flow, for during rainy periods the volume of sewage is often more than quadrupled. The Local Government Board requires that storm waters amounting to twice the dry-weather flow of

sewage must be treated in every respect as the sewage, while any additional quantity of storm water up to six times the dry-weather flow must receive special treatment, either by means of an artificial filter or by land used for no other purpose. The storm waters over and above six times the dry-weather flow may be discharged into a stream. Local authorities must therefore make provision for the treatment of six times the normal dry-weather flow.

The aerating filter-beds must be constructed of fine grain material. The nature of this material, given that it is hard and durable, does not appear to be a matter of prime importance. It may be of coal, cinders, coke, burnt ballast, gravel, or flint, and local circumstances may be left to determine which to select. Coke is generally scarce and expensive; coal is expensive, and, like burnt ballast, gravel, and flint, can often only be obtained by the payment of heavy charges for carriage. Sand and gravel do not appear to be so satisfactory as filters of coke, coal, and burnt ballast. In order to secure good and uniform results, the filters should not be made to deal with more than a million gallons of average sewage per acre per diem. The water capacity of these fine-grain beds diminishes somewhat with use, until as a rule a stage of equilibrium is reached, when the liquid capacity of the bed generally ranges between 25 and 30 per cent. of the total cubic capacity. The coarse coke breeze or burnt ballast beds used to receive crude sewage, however, separate a large proportion of the suspended matter of the sewage; hence their capacity for liquid generally settles down to a smaller proportion, represented commonly by a figure ranging from 15 to 20 per cent.

In all natural processes of sewage purification the

sewage must first of all be passed through a grit chamber in order to retain large mineral particles, which would otherwise find their way into the installation and accumulate there, organisms being of course quite incapable of attacking them.

What is essential in the working of a natural process is for the superintendent of the works to fully appreciate that he has countless colonies of living, working units under his control. Their work must always be regulated according to their powers, and sufficient and periodical intervals of rest must be allowed them between the regular periods of work. Then, and then only, will they attune their powers to the work they are called upon to perform, and so establish that equilibrium which is so easy to maintain, and so difficult to regain when once lost.

It is an interesting matter to note that the total nitrogen in organic combination in the sewage which enters any of these installations is not nearly accounted for in the NH_3, nitrates, nitrites, and the organic nitrogen still remaining in the final effluent. The loss is doubtless due to the fact that free nitrogen passes away from the beds (possibly also oxides of nitrogen), and a considerable amount of ammonia likewise.

On the ground that the micro-organisms concerned in purification are so dependent on oxygen for final and healthy fermentation, as opposed to putrefactive fermentation, that they will even reduce chemical compounds in order to use their available oxygen, Adeney advocates the feeding of the sewage with small quantities of an agent containing available oxygen, such as nitrate of soda or the manganate of soda.

Lowcock has devised a filter of sand and gravel which is kept aerated by pumping air into it, and which can be used continuously with good results. The intermediate

flushing of the filter-beds with water has been advocated by Lomain, Barwise, and others, and where practicable there is every reason to believe that a gain would result. Bostock Hill advocates the use of coal as a filtering material (Garfield's filter), the particles of coal being about the size of $\frac{1}{2}$-inch cubes at the bottom of the filter, and becoming smaller towards the top.

When certain trade effluents, especially waste acids, are passed into town sewage, experiment alone can decide whether it will be necessary to employ a preliminary chemical (lime) treatment prior to bacterial treatment in filter beds. It is certain that the natural agencies of purification are for the most part capable of dealing with such quantities of the trade effluents as more usually find their way into sewage. It would, however, be advantageous if manufacturers could be made to distribute the discharge of trade wastes more equally over the twenty-four hours. In some cases the waste products should undergo some purification or treatment before they are permitted to leave the premises on which they are produced.

Kenwood and Butler found that by the use of secondary filters (*i.e.*, double or treble filtration of the tank effluent from the anaerobic treatment of sewage) a much greater degree of purification can be obtained in a shorter time than by a single treatment of the tank effluent in one filter. A filter soon acquires a state of equilibrium, as regards powers of purification, which tends to adjust itself to an average of the strength of the polluting material with which it is day by day being supplied. It is for this reason that the necessity for multiple filters appears so great where strong, or alternating weak and strong, sewages have to be dealt with; for a filter will effect only a given percentage reduction on the pollution of the

sewage it receives, even when it has reached its maximum biological efficiency. If the pollution is high, and we represent the purification which can be effected by the filter as 50 per cent., the effluent may still be a bad one; but another 50 per cent. reduction in a second filter will leave only 25 per cent. of the original pollution still to be disposed of.

The point always to be borne in mind is that what has to take place is not merely the reduction of unstable matter to the ultimate stable condition, but the reduction of the more stable organic matter to the unstable. The reduction of the unstable to the stable or ultimate appears to be best effected by change of filters, that of stable to unstable by rest in a filter. High albuminoid ammonia in an effluent, then, is an index for rest in a filter; high oxygen absorbed is an index for passing to another filter under conditions permitting of good oxygenation.

Drs. Clowes and Houston advocate the use of coke for filters in pieces of about the size of walnuts, as the larger pieces enable the bed to hold a larger volume of sewage and to be more rapidly filled and emptied, as well as more effectively emptied and aerated. They find that in a bed 13 feet in depth the purification approximates to that in one 4 feet deep.

The purification may be expressed as a percentage calculated upon the reduction in the albuminoid ammonia and oxygen absorbed figures. In Mr. Dibdin's method such purification usually amounts to a little over 70 per cent. of the original pollution.

A bacterial filter of coke will cost from £2,000 to £4,000 per acre, and each acre will treat from 400,000 to 1,000,000 gallons daily, according to the nature of the sewage.

If the aerated beds are treated continuously, and good results can be got by this method, then the sewage must be applied evenly and equally over the whole area of the filter. It is difficult to effect this with ordinary fixed trough distributors; but it can be provided for by means of revolving sprinkling arms, such as Candy's, which automatically revolve horizontally over the bed, the motive-power being the passage of the sewage on its way to the sprinkling arms.

In Messrs. Whittaker and Bryant's installation, as the sewage passes to the sprinkler, a jet of steam is blown through it, which raises its temperature, the bacteria bed being thereby kept at an equable temperature very favourable to the activity of bacteria. It is also claimed that the application of the warm sewage to the surface of the bed causes an expansion of the air between the filtering particles; and, as a consequence, fresh air is drawn through the drain pipes at the bottom of the filter, and made to traverse the body of the bed, a high degree of aeration being thus assured. It is said that such a bed can deal with 600 gallons of sewage per square yard in twenty-four hours.

The artificial warming of bacterial beds, though it increases bacterial activity, is not necessary; for even in the coldest winter months the temperature of the body of the beds rarely falls below 60° F., though the temperature of the atmosphere may be below 40° F.

With the evidence at present available, it is extremely difficult to decide as to the respective merits of all of the installations which have been advocated. A proper comparison can only be made by arranging for the same sewage to be treated, at the same time, in the different installations, side by side; and if the matter is to be satisfactorily settled this is what will have to be done.

Sewage varies so much in its constituents, and in the relative proportions of its different constituents, that experiments performed on different sewages afford no precise information on which can be based a safe and scientific comparison.

Any opinion expressed must, therefore, be accepted with reservation, but probably every one of the methods referred to may be made to give satisfactory results. Questions of economy of plant and of time, of working and maintenance, and of the relative applicability of the process to local wants and conditions, must and will ultimately determine the choice.

The separation of the suspended solids by filtration appears to be the simplest and most rapid procedure; and upward filtration has the advantage over downward, that the sludge in this method requires no attention.

In judging of the working of any natural process of sewage purification, the mean results of twenty-four hours should be studied, but as a matter of fact during this time no very serious departure from the mean composition of the effluent is likely to take place. Hourly samples should be taken, and then these should be thoroughly mixed and a sample of the mixture analyzed.

A fair sewage effluent would have the following composition in 100,000 parts:

Saline and free ammonia	1·50
Organic ammonia	0·15
Oxygen absorbed in 4 hours at 80° F	1·50
Oxidized nitrogen	1·20
Chlorine	10·50
Suspended matter	2·15
Solids in solution	86·15
(*a*) Volatile	35·05
(*b*) Non-volatile	51·10

A satisfactory sewage effluent must be without fæcal

odour and practically colourless. In the opinion of many, the organic ammonia figure is the best criterion of a satisfactory effluent. It is held by some authorities that this figure should not exceed 0·1 part per 100,000, while others advocate a limit of 0·15, or even 0·2. The oxygen absorbed by oxidizable organic matter in four hours at 80° F. does not exceed 1·5 parts per 100,000 in good effluents. The chlorine and free and saline ammonia figures are unimportant, since these are ultimate products; the chlorine in the effluent of a sewage of average strength is about 10 parts per 100,000. There should be practically no solids in suspension; the Rivers Pollution Commissioners' standard required that the suspended matter should not exceed 3 parts of dry mineral matter per 100,000, nor 1 part of dry organic matter per 100,000. Above all, the final effluent must not be liable to putrefaction or secondary decomposition.

The presence of oxidized nitrogen in an effluent must not be regarded as an index of purity, although if nitrates are found to persist in the effluent for a few days after its collection, the effluent is not likely to become offensive. Nitrates are a measure not of that pollution which may be oxidized, but of that which has been oxidized, and their presence gives no indication of what remains to be purified.

The fact is that no general standard applicable to all cases is possible or desirable. The best possible results must always be aimed at, and should be insisted upon, having due regard to the nature of the sewage, and to the conditions, volume, and uses of the stream which is ultimately to receive it. The maximum impurity permissible will in certain cases be very slight indeed, while in others a greater latitude may be conceded.

Intermittent Downward Filtration.

When sewage is filtered through porous soil, it is purified to a greater or less extent. This purification is partly due to the soil acting as a mechanical filter, separating out and retaining the suspended matters in the sewage; but greatly more to the destruction by organisms of the organic matters in the sewage. This purification is chiefly effected by bacterial organisms—the nitrifying organisms of Schloesing, Müntz, and Warrington—which exist in the upper layers, extending to 3 or 4 feet from the surface, of all soils, but chiefly in those rich loamy soils which contain much organic matter. The nitrifying organisms feed on the organic matters of sewage, causing their oxidation. They require air and oxygen for their growth and life, which are supplied to them when the soil is being aerated during its periods of rest. The soil or the sewage should also be rich in lime or other alkali; for the nitric and nitrous acids formed by the nitrifying organisms must be able to combine with bases, or the nitrifying action ceases.

A very large volume of sewage can be purified on a small area of land, if the soil is of a porous and rich loamy character. Sandy soils are not efficient purifiers—at any rate, at first. Clay, and other retentive soils, must be well broken up and mixed with ashes. The surface of the land must be levelled, and underdrained with porous tile drains, laid at a distance of about 10 to 30 feet apart, according to the nature of the soil, and at a depth of 5 or 6 feet from the surface. The area should be laid out in plots; and no plot should receive sewage for more than six hours, so that it may have eighteen hours' rest out of the twenty-four; to this end the screened, filtered,

or precipitated sewage is distributed over each plot of ground intermittently by means of branching carriers. If it is intended to apply the sewage in the proportion of more than 1,000 people to an acre, the sewage should be treated chemically to remove the suspended matters, and the clarified sewage only should be applied to the land.

When crude sewage is applied in large volumes to a small area of land, the pores of the soil become clogged with the slimy suspended matters, and a kind of coating is formed over the surface, which prevents the percolation of the sewage and the penetration of air into the interstices of the soil. When the sewage of considerably less than 1,000 people is to be applied per acre, the screened sewage may be applied in its crude state; for it is much cheaper to allow the suspended matters to reach the soil by gravitation in the liquid sewage, than to separate them by precipitation and then, as is sometimes necessary, to pump the liquid sludge on to the land. It is generally the practice to lay out the filter areas in ridges and furrows, the sewage being allowed to flow down the furrows, whilst vegetables are grown on the ridges. The roots of the vegetables assimilate organic products, and thus help to purify the sewage, whilst the leaves and stalks, being above the sewage, are not contaminated by floating matters. The suspended matters deposited from the crude sewage in the furrows must be dug into the soil from time to time, before they have time to form an impenetrable coating.

By intermittent downward filtration through specially prepared filter-beds, the clarified sewage of even 5,000 people can be applied to each acre of filter; but it is not really safe to allow less than 1 acre to each 1,000 of population when the intermittent downward filtration is through

soil, however suitable the soil may be. Under favourable circumstances, the effluent water issuing from the drains will be found almost completely free from organic matters. The nitrogen of the sewage exists in the effluent water, but in the innocuous forms of ammonia, nitrates, and nitrites. The chlorine will be found in about the same proportion in the effluent as in the sewage. The sewage, therefore, by this process is effectually purified; but all its manurial ingredients are wasted, except in those cases where the sale of vegetables, grown on ridges, covers part of the cost of the distribution. But the area of land being so limited, the amount of crops, and the income derived from their sale, must necessarily be very small.

Irrigation.

In the words of the Royal Commission on Metropolitan Sewage Discharge, broad irrigation means "the distribution of sewage over a large surface of ordinary agricultural ground, having in view a maximum growth of vegetation (consistently with due purification) for the amount of sewage supplied." Filtration means "the concentration of sewage, at short intervals, on an area of specially chosen porous ground, as *small* as will absorb and cleanse it: not excluding vegetation, but making the produce of secondary importance. The intermittency of application is a *sine quâ non* even in suitably constituted soils, wherever complete success is aimed at."

It becomes necessary to inquire what are the conditions under which the sewage of a town may be applied to land by broad irrigation; that is, how may sewage farming be rendered successful? Experience has taught

that no great profit should be looked for from a sewage farm; but even if the sale of the produce helps to diminish the cost of purification, this is a result which can be attained by no other method of disposal of sewage. Unfortunately, in the past, local authorities have found great difficulty in acquiring land for purifying sewage. Enormous prices have been asked and given for agricultural land, required for sewage farms; and these, added to Parliamentary and legal costs, have in many instances saddled the rates with burdens, which cannot possibly be defrayed by the sale of sewage-grown produce.

In the first place, the land chosen should be so situated in relation to the town that the sewage may flow to it by gravitation: pumping is costly, and greatly reduces any profits that may arise. The rent to be given for the land ought not to exceed £2 10s. per acre (Bailey Denton). The extent of land that should be acquired varies under different circumstances; as an average, 1 acre to every 100 to 200 persons of the population is sufficient. The best kind of soil is a friable loam, but clayey, gravelly, or sandy soils are all capable of purifying and utilizing sewage when properly managed. The land must be levelled, and, unless very porous, under-drained to allow the sewage to percolate and prevent its stagnation on the surface. With very dense clay soils filtration is impossible, and in such cases surface flow must be entirely relied upon. This is capable of giving a fairly pure effluent, if the sewage has been freed of suspended matters by a preliminary precipitation, and if the area of the land is sufficient. In these cases under-drainage should not be attempted, as in dry summer weather the stiff clay soil cracks, and the sewage may pass away directly through the fissures into the under-

drains, and so reach the watercourses unpurified. The main carriers for the distribution of the sewage on the farm should be masonry, concrete, or stoneware channels, which can be easily flushed and cleansed.

Great care must be exercised where sewage is allowed to irrigate land of a chalky nature, or where a top layer of clayey soil of but little thickness covers a thick stratum of chalk. In certain chalk formations, what are known as "swallow-holes" exist—that is, extensive fissures in the chalk reaching up to the surface. In such soils it sometimes may happen that unpurified sewage flowing over the surface may disappear into one of these fissures or swallow-holes and pollute the underground water, which at no great distance away may be pumped out of a deep well in the chalk to supply houses, villages, or towns. Such an occurrence is believed to have occurred at the East Riding Lunatic Asylum, near Beverley, Yorkshire. The top layer of clay became extensively cracked in dry summer weather, permitting unpurified sewage to pass through to the chalk beneath, where it was conducted by fissures to the deep well, about half a mile distant, which supplied Beverley with water. As the water in this well is sometimes depressed by pumping to the extent of 17 feet, the area of the circle drained by the well must be very extensive. In the immediate neighbourhood, a stream much polluted by the sewage of a village on its banks disappeared into one of these swallow-holes, where the chalk rises up into the bed of the stream.

The method most capable of general application for applying the sewage from the main carriers to the surface of the farm is that known as the *ridge and furrow* system. The surface is laid out in ridges—30 to 60 feet broad—running parallel to each other, and at right angles to the

main carrier, with a slight fall from it. Between every two ridges is a furrow formed by the slope (a fall of a few inches) of the two ridges towards each other. The sewage is made to pass down a grip in the centre of the ridge, and thence to flow over the sides towards the furrow. When the central grip becomes clogged with the suspended matters of the sewage, it should be filled in, and a fresh one made in its place. The underdrains of porous earthenware should be laid at a depth of about 6 feet in the soil, and from 20 to 100 feet apart, according to the porosity of the soil.

What is known as the "catch-water system" of irrigation can be adopted where the areas for sewage treatment have sufficient gradients. By this method a series of furrows or trenches are dug in lines one below the other. The sewage is conducted to the topmost trench, over which it flows to find its way into the next lower trench, and so downwards to the bottom of the slope, where the effluent is collected and conveyed away in drains.

The best crops for a sewage farm are Italian rye-grass, roots (mangold wurzel), and cabbages. Messrs. Rawlinson and Read in their report to the Local Government Board (1876) state: "Italian rye-grass is probably in all respects the most advantageous crop to be grown under sewage, as it absorbs the largest volume of sewage; occupies the soil so as to choke down weeds; comes early into the market in spring; continues through the summer and autumn, bearing from five to as many as seven cuttings in the year, and producing from 30 to 50 tons of wholesome grass upon each acre." After two or three years, the plot of rye-grass should be ploughed up, and the land sown with cabbages or roots (mangolds). These may be sewaged when growing, but they should

not be sewaged when they arrive at maturity. They help to exhaust the soil of the sewage products retained in it, which have not been absorbed by the rye-grass. Pulse, cereals, and all other vegetables, should not be sewaged when in growth, except in times of great drought. The land, when fallow, may be enriched by the application of sewage ; for some of the manurial ingredients of sewage are doubtless retained in it, ready for use on a future occasion. Market-gardening may be undertaken, and made very profitable on farms where the area of land is more than sufficient to deal with all the sewage ; but, where this is not the case, market-gardening does not answer, because the area so cultivated cannot deal with all the sewage which it ought to utilize.

The amount of capital required to stock and work a sewage farm is very great, probably five times the amount required for an ordinary farm. The crops that have to be taken off the land are enormous, and a large amount of labour is required to keep it clean and free from weeds. The crops of Italian rye-grass, being so large, may—and often do—exceed the demands of the local markets. If not sold at once, the grass is wasted ; for it will not keep, and will not bear long carriage. In dry summers it may be made into hay, and at other times it may be converted into ensilage. It has been found, however, that, to reap the greatest profits from a sewage farm, the produce should be converted into milk and meat. In other words, a dairy farm should be established, and stock should be reared and fattened for market. The idea that sewage-grown produce is dropsical and prone to decompose has been long exploded. The milk and meat, also, from animals fed on such produce in no way differs from milk and meat produced on ordinary farms.

From experiments extended over five years (1871-76), the British Association Sewage Committee found that the average amount of nitrogen recovered in the crops of a sewage farm was 32·88 per cent. of that applied in the sewage. About 11 per cent. of the nitrogen in the sewage escapes in the effluent water, almost entirely as nitrates and nitrites, whilst a portion of the unaccounted-for nitrogen is stored up in, and enriches, the soil of the farm. These results the committee considered very satisfactory, taking into account the extreme porosity of the soil and the limited area of the land of the farm experimented on, as in the experiments of Messrs. Lawes and Gilbert only from 40 to 60 per cent. of the nitrogen applied in solid manures was recovered in the crops within the season of application.

The amount of evaporation of water from the surface of a sewage farm is enormous. The above committee found that, on an average of over a year's observations, only 47·3 per cent. of the sewage pumped on to the land was discharged through the deep drains as effluent water. This fact must be reckoned with on making analyses of effluent water from sewage farms, which are to be compared with samples of crude sewage flowing on to the farm. Although the evaporation of water is so great, the committee found that there was no loss of ammonia from the sewage by evaporation in its passage along the open grips and carriers on the farm.

One of the great drawbacks to the utilization of sewage by irrigation is the fact that the sewage must be applied to the land as it comes, by night as well as by day; on Sundays as well as on week-days. There may be times when it may not be desirable to apply sewage to the general surface of the farm, especially during wet weather, when enormous volumes of dilute sewage arrive at the

farm. This difficulty may be got over by laying out a portion of the farm as a filter-bed closely drained. The extent of this filtration area should be sufficient to purify the whole of the sewage when not required on the general surface of the farm. The land may be left fallow, or laid out in ridges and furrows and cropped. When the sewage is much diluted with storm water, it may, in other cases, be carried over a specially prepared filtering area planted with osier-beds, or over meadow lands, before being discharged into a stream. The flow of sewage is thereby checked, and suspended matters are to a certain extent deposited, so that the sewage is partially clarified before its entrance into the stream. It would be of great advantage if storm and subsoil waters could always be excluded from the sewers: the problem of satisfactory disposal of the sewage would be thereby greatly facilitated.

During the most severe frosts irrigation may continue uninterruptedly. A coating of ice is formed over the surface of the farm, but the sewage, which always has a temperature well above the freezing-point, flows underneath this coating and sinks into the soil, which remains unfrozen and open. As the weather moderates, the sewage rapidly melts the ice above it. Even in America, where the frosts are most intense, no trouble has arisen from this cause on any of the sewage farms.

Are sewage farms productive of nuisance and injury to health? There can be no doubt that badly managed farms—where more sewage is applied than the land can absorb and cleanse, or where, from the sewage being applied too continuously, the surface becomes sodden, and ponded sewage stagnates on it—may be a nuisance. That they can cause injury to health or produce disease has yet to be proved. When properly conducted, and the sewage is distributed over the land in as fresh a state

as possible, and not after prolonged sojourn in a lengthy main sewer, sewage irrigation is not found to be productive of any nuisance.

That sewage farming is no more unhealthy than ordinary farming is shown from the returns of the nine sewage farms which were in competition for the Royal Agricultural Society's prizes. The rate of mortality amongst the labourers and their families, on an average of the number of years these farms had been in operation, did not exceed 3 per 1,000 per annum. No facts, either, have ever been brought forward in favour of the view that entozoic diseases are spread by the agency of sewage farms. It is probable that alkaline sewage destroys organisms like the ova of tapeworms, whose natural habitat is the acid secretion of the human intestines. If so, they are destroyed before they arrive at the farm. On one farm, too, it was found that there was a remarkable absence of those molluscan and insect forms of life which frequently play the part of intermediary bearers to entozoal larvæ, and without which the cycle of their existence cannot be completed. Even where cattle have been allowed to feed upon land to which sewage was being applied, it has not been found that they were in any way affected with parasitic diseases.

CHAPTER III.

AIR AND VENTILATION.

PURE atmospheric air has the following volumetric composition :

Oxygen	20·91 per cent.
Nitrogen	76·95 ,,
Argon	1·00 ,,
Carbonic acid	0·04 ,,
Aqueous vapour	variable

Traces of organic matter, ozone, mineral salts, ammonia, nitric acid, krypton, neon, metargon, carburetted hydrogen ; and in towns sulphurous acid and sulphuretted hydrogen.

This composition is, as regards the three gases which compose almost the entire bulk of ordinary air, remarkably uniform in every part of the world. Even in the midst of large cities, where the atmosphere is being vitiated and polluted in every conceivable variety of way, the air of open spaces differs but very slightly in the proportions of its constituent gases from the air on the open plains, mountains, or seas, which is far removed from such sources of contamination. This is not to be wondered at when the immense power and universality of the forces which promote purification of the atmosphere are considered. Such are: The winds, which dilute and sweep away impurities, bringing pure air in their place ;

the rain, which washes the air, carrying down in its fall dissolved gases and suspended impurities; the chemical effects of the oxygen and ozone in the air on the oxidizable matters in it; and, lastly, the power possessed by the green parts of plants in sunlight of absorbing carbonic acid, fixing the carbon, and setting free the oxygen. The latter process is, however, reversed during the hours of night, CO_2 being evolved, but the balance is decidedly in favour of purification.

But under the artificial conditions of civilized existence it too often happens that the utilization of these purifying forces—the science of ventilation—is not understood, or is neglected, and as a consequence the impurities, which are continually being thrown by human agencies into the atmosphere, increase faster than they can be dispersed or destroyed. Confining our attention for the present to the outer air—the air outside buildings—it has been found in large cities that when the atmosphere is stagnant, and no wind is blowing, especially during fogs, the air of open spaces may contain only 20·80 per cent. of oxygen, or even less, and the carbonic acid may exceed 0·06 per cent., with a considerable increase likewise in organic matters. Such observations have been made in London and Manchester. In the narrow closed courts or streets, surrounded by high buildings, which constitute so large a portion of the densely populated parts of these cities, the air has been found considerably more impure than the samples above given, which were taken from open spaces. The air of such places is stagnant and confined, as in a well; there is no circulation to effect a proper renewal of fresh air, and dispersion of accumulated impurities, and the sun rarely penetrates. Yet such is the only air-supply attainable by thousands of the dwellings of the poorer classes.

Ozone, which is oxygen in an allotropic and highly active condition, is generally absent from town air, even in open squares and parks.

We thus see that although in towns much may be done by constructing wide and airy streets, by preventing the back-to-back aggregation of dwellings, and by suitable restrictions as to their height, to provide for proper ventilation and purification of the atmosphere, yet its purity is liable to variations, which do not occur in the air of the open country. These variations may be only very slight in amount, but they are not unimportant. Their bearing on the health and vitality of the populations exposed to their influence is probably considerable.

Amongst suspended matters usually present in the air, to a greater or less extent, are minute particles of mineral matter (common salt, especially near the sea), soot, dust of various kinds—in towns consisting largely of organic matters from horse-droppings—vegetable débris, pollen of grasses and flowers in the early summer, the spores of various fungi and moulds, diatoms, bacteria and their spores, monads and infusoria—dead and living. The purest air, such as exists at considerable elevations on mountains and over the sea, contains but very little suspended matter. In towns, especially manufacturing towns, the air is often loaded with soot and dust of mineral origin. The dust in the atmosphere provides innumerable nuclei for the condensation of moisture or water vapour.

In towns, the amount of organic and mineral dust in the air will depend greatly on the efficiency of the scavenging and watering of the streets. The wind raises minute particles from the surface of the ground, and carries them often great distances before they are de-

posited. In this way infectious particles from domestic dust-heaps and dried excreta may be caught up and carried into the air.

Air is vitiated by *respiration of men and animals; by combustion of coal, gas, oil, etc.; by fermentation and putrefaction of animal and vegetable organic matters; by various trade and manufacturing processes.*

Vitiation by Respiration.

An adult individual at rest breathes at the rate of about seventeen respirations a minute. At each respiration about 500 c.c. (30·5 cubic inches) of air pass in and out of his lungs. The air in the lungs loses 4 to 5 per cent. of oxygen, which is absorbed by the blood in the pulmonary capillaries, and gains carbonic acid from the venous blood to the extent of about 4 per cent. The nitrogen remains unchanged.

The composition of respired air is variable, but may be taken to be somewhat as follows: Oxygen, 16·96 per cent.; nitrogen, 79·00; carbonic acid, 4·04. In addition, the expired air is raised in temperature to nearly that of the blood, 98·4° F.; it is saturated with aqueous vapour, and contains a considerably larger proportion of putrefiable organic matters than the air which is inspired.

The amount of carbonic acid which is given off by an adult male person at rest can be calculated from the above figures, and will be found to be 0·72 cubic foot in one hour. From actual experiment it has been determined that an average adult gives off 0·9 of a cubic foot of CO_2 during gentle exertion, and as much as 1·8 during hard work. The adult female gives off about one-third less of each of these quantities under similar circumstances, and an infant is said to give off about 0·5 cubic foot of CO_2 per hour. In a mixed assembly of male and

female adults and children the CO_2 given off per head is therefore taken as 0·6 of a cubic foot.

The organic matter given off by the skin and lungs varies with the individual and his state of health. It consists of vapour from the lungs, of suspended matters (epithelial and fatty débris) from the mouth, and of volatile fatty acids from the skin; it is nitrogenous and oxidizable, and very rapidly putrefies. It is also absorbed by hygroscopic substances, such as wool, feathers, and moist paper; and is noticeable by smell in the air of an inhabited room, when the CO_2 exceeds 0·06 per cent. This foul organic matter is probably the substance which renders air much vitiated by respiration so peculiarly deleterious to health; but the most recent research rather points to the view that excess of CO_2 and deficiency of O also play a considerable part in the deterioration of health due to breathing vitiated air, combined possibly with the high temperature of the air.

The amount of watery vapour given off by the lungs and skin is about 550 grains per hour—enough to saturate 90 cubic feet of air at a temperature of 60° F.

Inasmuch as foul organic matters are present in air vitiated by respiration, very much in proportion as the CO_2 is in excess and the oxygen diminished, and as the amount of CO_2 is estimated so much more easily than the organic matters, it is usual to judge of the foulness of the air of inhabited places by the excess of CO_2 in it. The organic matters in an inhabited room are difficult to get rid of even by free ventilation—unlike the CO_2, which, being nearly equally diffused throughout the apartment, is rapidly removed when there is a communication with the external air.

The number of microbes present in air vitiated by respiration seems to bear no very definite relation to the

amount of CO_2 gas present. This is not to be wondered at when we know that the greatest numbers of microbes are found in the air which contains the largest amount of dust, and that the air of inhabited places may be stagnant and therefore free from dust, although much polluted by respiration. It appears also that the microbes and dust particles in the air we breathe do not as a rule reach the lungs, but adhere to the moist membranes lining the mouth, nose, and throat, and are got rid of by the mucous excretions of these membranes. The air reaching the lungs is consequently, as a rule, sterile; and the respired air is also devoid of organisms. It is probable that the infective organisms present occasionally in the air are absorbed into the system, after being deposited on the mucous surfaces of the nose, tonsils, or palate, and only occasionally reach the air cells or bronchi of the lungs.

The purity of the air in dwelling-rooms depends upon the amount of cubic space for each individual and the facilities afforded for entrance of fresh and exit of foul air. Where these points are properly attended to, the air, although rather more impure than the external atmosphere, will not be productive of injury to health. In those extreme cases where many people are crowded together, and the ventilation is totally inadequate, the air often becomes sufficiently impure to cause headache, lassitude, nausea, and fainting. In the pit of a theatre at 11.30 p.m., Dr. Angus Smith found the oxygen reduced to 20·74 per cent.; and in the old court of Queen's Bench in 1866 the oxygen on one occasion was as low as 20·65. In a schoolroom crowded with seventy girls Pettenkofer found the carbonic acid to exist in the air to the extent of 0·723 per cent., or nearly twenty times the amount normally present in air; whilst the

organic matter, measured as albuminoid ammonia (usually present in pure air to the extent of 0·08 milligramme per cubic metre) has been found in the ward of a hospital to reach 1·3 milligrammes per cubic metre of air.

The above figures represent in each case excessively foul atmospheres; all intermediate conditions of air, varying according to circumstance, may be found in the different kinds of inhabited rooms and dwellings. The long-continued breathing of even much less vitiated air than the above samples is, perhaps, one of the chief causes of rickets in children, and tends to produce a lowered state of vitality in older people, characterized by anæmia, dyspepsia, and lassitude. People in this lowered condition of health, which is very common amongst those who spend the greater portion of every day indoors, in offices, schools, workrooms, and factories, offer much less resistance to attacks of acute disease than do people who live out-of-door lives; and they are greatly more subject to all chronic and wasting diseases. Dr. Ogle's researches have shown that, of all the industrial classes, those which are the healthiest and have the lowest death-rates are the gardeners, farmers, agricultural labourers, and fishermen—those, namely, whose occupations are carried on in the open air. The death-rate from phthisis in these classes is only half that of the male community generally, and they enjoy about the same amount of freedom from diseases of the respiratory organs. Differences in food or housing accommodation cannot account for the comparative freedom of these classes from pulmonary disease. The average agricultural labourer is probably worse housed and fed than the town clerk or mechanic, but he spends the greater part of his life in the open air instead of in a vitiated atmosphere.

The causal relation subsisting between foul air, produced by overcrowding and insufficient ventilation, and phthisis is now generally recognised. The most convincing proofs of such a relation are to be found in the comparative immunity enjoyed by soldiers, sailors, and prisoners at the present time from this disease. Formerly, owing to the very limited amount of cubic space allotted per head, and the disregard paid to ventilation, phthisis was considerably more prevalent among soldiers, Royal Navy sailors and marines, and prisoners in Her Majesty's gaols than amongst the males of the same age in the classes from which they were derived. At the present time, other conditions, such as food, exercise, etc., remaining much the same, the death-rate from phthisis is considerably less amongst these servants and prisoners of the State than amongst the civil population.

The theory of the contagiousness of phthisis, long ago held by those who, like Dr. Bryson, had observed the rapidity with which destructive lung diseases spread in an overcrowded community, has received the strongest confirmation from the discovery by Koch of the tubercle bacillus, an organism invariably present in tubercular deposits, but not found in any other disease. The tubercle bacillus is present in the sputa, and may be thus transferred through the air as dust from dried sputa, to the lungs of the healthy, under conditions of too close crowding, but not apparently where matters of cubic space and ventilation are attended to, as phthisis is not found to spread in the well-ventilated wards of general hospitals. In fact, there is reason to believe that the bacilli acquire more virulent infective powers in the foul atmospheres of overcrowded rooms and damp houses, than they originally possessed on leaving the lungs of a phthisical person. Whatever the explanation may be,

it seems clear that phthisis is intimately connected with air vitiated by the products of respiration, or by the moisture and organic effluvia arising from damp and dirty soils, and that if such conditions are absent its capability of spreading is very limited.

The incidence of disease on the inmates of back-to-back houses, in which there can be no through ventilation and circulation of air, has been investigated for the Local Government Board by Dr. Barry and Mr. Gordon Smith. They report that it appears probable that the want of through ventilation has, *per se*, an unfavourable influence upon health, and gives rise to an increased mortality from pulmonary diseases, phthisis, and diarrhœa. Dr. Ransome has also brought forward evidence to show that in Manchester and Salford the streets most infested with phthisis are also the most confined and ill-ventilated, and that the larger proportion of these deaths take place in the cavelike back-to-back dwellings.

Acute diseases of the lungs, especially bronchitis and pneumonia, are very prevalent amongst those who live in heated, overcrowded rooms. The relation of pneumonia to vitiated air is especially interesting, as this disease occasionally appears to take on an epidemic form and to be infectious. In some cases of acute infectious pneumonia, a micrococcus has been found in the diseased tissues which has been supposed to be the specific cause of the disease.

An extensive outbreak of epidemic pneumonia at Middlesbrough was investigated by Dr. Ballard. The disease, which was distinctly infectious, had an exceptional incidence on males above the age of fifteen. The contagion was apparently transported directly through the air, by means of the breath, from the sick to the healthy, and also by means of infected sewer and drain

emanations, and by food. Dr. Klein discovered a bacillus, in the lung juice and fresh sputa, which he regards as specific.

The zymotic diseases generally are more prevalent amongst overcrowded populations than amongst those who are better lodged; but this may be accounted for by the inability to isolate infectious cases, and consequently the ease with which contagious particles pass from the bodies of the sick to those of the healthy. Air vitiated by the ordinary products of respiration of a healthy person may produce illness, but cannot be productive of a specific disease.

In this connection we may consider the contamination of air by exhalations from the person generally. The disagreeable odour perceived in the near neighbourhood of dirty people arises from exhalations of putrid organic matters from their bodies and clothes. The air of a London police court furnishes a striking example of such air pollution. But it is especially the exhalations from the sick that are important and require notice, from the part which they play in propagating disease.

In the air of ill-ventilated sick-rooms and hospital wards the débris of dried epithelial scales and pus cells may often be found floating. These matters are especially frequent in wards where many of the patients have purulent discharges from suppurating wounds or copious expectoration from the lungs, and are usually accompanied by an abundance of spores of fungi and bacteria, and large excess of organic matters generally in the air. In many persons the breathing of such polluted air causes an immediate effect on the throat and tonsils, passing sometimes into acute tonsillitis or hospital sore throat. Its effect in increasing the severity of, and in retarding recovery and convalescence from acute disease,

is now generally recognised. Patients suffering from erysipelas, ophthalmia, pyæmia, septicæmia, and hospital gangrene, are undoubtedly infectious to those who have open wounds. The contagious particles (pyogenic micro-organisms of various kinds)—contained in dried epithelial scales and pus cells—may be transferred through the air from patient to patient; and often no measure short of emptying the ward appears to be of any avail to stop an epidemic once begun. In times not very far distant, these diseases were, in the surgical wards of many hospitals and infirmaries, almost constantly present. Freer ventilation, improved sanitary arrangements, and the antiseptic treatment of wounds and injuries, have almost eradicated such calamities from modern hospital practice.

The transmissibility of the acute specific fevers through the air from the bodies of the sick is universally recognised, but not so the infectiousness of phthisis, diphtheria, and typhoid fever; and it is usual even now to place such cases in wards occupied by patients suffering from different diseases. In the light of recently acquired knowledge this is a practice not unattended with danger, and a feeling is gaining ground that special wards should be provided for these three diseases no less than for cases of erysipelas, pyæmia, and hospital gangrene. It is possible that parasitic skin diseases may spread through the air, for sporules and mycelia of *Tricophyton tonsurans* and *Achorion Schönleinii* have been found floating in the atmosphere of wards occupied by patients suffering from diseases of the skin.

Vitiation by Combustion.

There are three kinds of mineral coal—anthracite or smokeless coal, bituminous coal, and lignite. Bitumin-

ous coal is used exclusively in the manufacture of illuminating gas. Anthracite is a sort of natural coke, most of its gases having been driven off during the process of formation. The bituminous kind is the only one used for domestic fireplaces, although anthracite, being smokeless (no soot), when used in properly constructed stoves, would be far preferable. Bituminous coal when burnt in an open fireplace gives off nearly three times its weight of carbonic acid, small quantities of carbonic oxide, sulphurous acid, bisulphide of carbon and sulphuretted hydrogen, and steam. About 1 per cent. is given off as fine particles of carbon or soot and tarry matters. One pound of coal requires 240 cubic feet of air for complete combustion.

Illuminating gas is obtained by the destructive distillation of coal in retorts, without access of air. The gas is subsequently purified by condensation to remove tar and water, and its temperature is reduced to about 60° F. If the temperature of the gas is lowered below 58° F., naphthaline and other valuable illuminants are deposited, and the gas is impoverished. The crude gas is then passed through a scrubber, which is a large chamber so arranged as to offer a large surface, constantly sprayed with water, to the gas. The water absorbs nearly the whole of the ammonia from the gas, and a certain quantity of the ammonia and sulphur compounds. This water impregnated with ammonia and its compounds forms the "gas liquor" or crude ammoniacal liquor of commerce. The gas is then led on to the purifiers, formed of lime or sesquioxide of iron, or both, and here the carbonic acid, sulphuretted hydrogen, bisulphide of carbon, sulpho-cyanides, and other offensive sulphur compounds, are removed, or at least reduced in the gas to a practically non-injurious

quantity. The standard adopted by the Metropolitan Gas Referees requires all gas to be quite free from sulphuretted hydrogen; the maximum of sulphur (in compounds other than H_2S) must not exceed 17 grains per 100 cubic feet, nor the ammonia 4 grains per 100 cubic feet.

When purified, coal gas contains, on an average: hydrogen 47 per cent., marsh gas 35 per cent., carbonic oxide 6 per cent., illuminants (ethylene, acetylene) 6 per cent., carbonic acid 1 per cent., nitrogen, sulphurous acid, etc., 5 per cent. The products of combustion of coal gas are nitrogen 67 per cent., water 16 per cent., carbonic acid 7 per cent., carbonic oxide variable—least when combustion is most perfect—sulphurous acid and ammonia. One cubic foot of average gas combines with the oxygen of from 5 to 8 cubic feet of air, and produces when burnt about $\frac{1}{2}$ cubic foot of CO_2, and from 0·2 to 0·5 grain of SO_2, and is able to raise the temperature of 31,290 cubic feet of air 1° F. One cubic foot of CO_2 is produced by the combustion of about 300 grains of oil in a lamp.

A common gas-burner consumes on an average about 4 cubic feet of gas per hour, and furnishes, therefore, about 2 cubic feet of CO_2 in that time. If this CO_2 is to be brought down to 0·6 per mille, 10,000 cubic feet of fresh air would have to be supplied per hour for each such burner. But this is not necessary, for the CO_2 from such a source is not accompanied by the harmful organic impurity which accompanies that derived from human respiration; and indeed, when adequate measures are adopted for purifying coal gas, its products of combustion contain but little impurity. It will therefore be sufficient to dilute the CO_2 from such a source to bring it to about 0·8 or even 1 part per 1,000; and it is

generally held that about 1,200 cubic feet of fresh air supply is amply sufficient for every cubic foot of gas consumed. A "standard" sperm candle (six to the pound), and burning 120 grains per hour, gives off about 0·4 cubic foot of CO_2 per hour; and about 1,000 cubic feet of fresh air should be supplied.

All these products of combustion eventually escape into the outer air, where they are rapidly diffused and diluted, with the exception of the sooty particles which accumulate in the lower strata of the atmosphere and are only dispersed by strong winds and rain. The sulphurous acid in the air of towns may cause the rain to be acid, and has a very destructive effect on vegetation, mortar, and the softer kinds of building stone. The products of combustion of coal gas usually escape into the air of the rooms where the gas is burnt, and serve to intensify the ill-effects on health of air already vitiated by respiration. Carbonic acid when present in the air even to the extent of 2 per cent., if unmixed with other impurities, appears to have no very injurious action on health; but above this quantity it produces headache and nausea, and if present to the extent of 10 per cent., or even less, it produces rapidly fatal results. Carbonic oxide, on the other hand, is very poisonous. As little as 0·4 per cent. in the air may cause death from asphyxia, the gas uniting with the hæmoglobin of the red corpuscles and displacing the oxygen, so that the red corpuscles can no longer act as carriers of oxygen to the tissues, and failure of the chief nervous centres results. It therefore acts as a powerful narcotic, and exerts its effects in a most insidious manner; for being destitute of odour, and not causing any irritation of the air-passages when inhaled, it may be breathed unconsciously by the victim, who quickly experiences a loss of the power of movement,

and even of any desire to make an effort to escape from the poisoned atmosphere.

The sulphurous acid and soot in the general air of towns like Manchester, Liverpool, and London, appear to have no very marked effect on healthy people ; but they are undoubtedly injurious to many asthmatics and to people suffering from bronchitis. During dense fogs the mortality from lung diseases always increases. Yellow town fogs are due to the suspended particles of moisture in the air (which constitute a mist) becoming enveloped in a greasy coat of mixed carbon and hydrocarbons. The mist is thus rendered yellow and opaque, the light of the sun cannot penetrate, whilst the sulphurous products contained in the fog are extremely irritating to the respiratory mucous membranes.

Corfield has called attention to cases of relaxed and ulcerated sore-throat caused by slight escapes of coal gas into houses from defective pipes or burners. Coal gas also occasionally finds its way into houses from leaky or fractured mains in the street. The gas passes through the soil and escapes under the basement floor, or even finds its way up the walls behind panelling. When the escape is large in amount, the effects produced on persons inhaling the gas are of an asphyxial type due to the contained carbonic oxide ; but when the escape is small, but long continued, the sulphur compounds, and especially the bisulphide of carbon, appear to be the injurious factors affecting the throat. These effects of escape of gas would probably be most intense where the gas is insufficiently purified after manufacture.

The method usually adopted for testing the soundness of gas pipes and fittings is to subject them to air-pressure by means of a force-pump. A pressure-gauge is attached to one of the burners, and air is forced into some other

connected pipe until a pressure of 5 or 6 inches of water is registered on the gauge, when the stopcock on the force-pump is closed. If the pressure-gauge reading is not maintained after a few minutes, the pipes or fittings are not sound.

Sulphur compounds may also gain access to the atmosphere of occupied rooms from leaky chimney-flues. A chimney-flue may be tested very much as a drain; the outlet should be sealed from the roof, and one or more smoke rockets discharged from the fireplace, the opening of which must be subsequently sealed with a large piece of gummed paper; the smoke will then escape at any defective parts of the flue.

Vitiation of Air from Decomposition of Organic Matters.

Animal and vegetable organic matters in cesspools and in badly constructed sewers and drains ferment and putrefy, disengaging gases, some of which are fœtid and highly complex bodies, probably carbo-ammoniacal and allied in chemical constitution to the compound ammonias (methylamine and ethylamine), whilst others are the simple gases, carbonic acid, sulphuretted hydrogen, ammonium sulphide, carbon bisulphide, carburetted hydrogen, nitrogen, etc. Recent research tends to show that the organic vapours arising from decomposition of animal substances may contain traces of the animal alkaloidal substances—ptomaïnes and leucomaïnes—which are contained in the fæcal and urinary excretions of the animal body, and which exert a directly poisonous action on the system. The carbo-ammoniacal vapours have a strongly offensive odour, and are found in the air of cesspools and sewers where fermentative processes are in action. The suspended particles in cesspool or sewer

air are dead organic débris and living organized germs (bacteria, moulds, and fungi, and their spores).

The micro-organisms—the bacteria and fungi—are the constituents of sewer air to which attention has been lately most directed. The earlier researches on the subject were for want of means necessarily very inadequate. The net result of the later observations is to show that, contrary to what might have been expected, sewer air is under ordinary conditions remarkably free from the microbes which are capable of cultivation on solid nutrient media at ordinary temperatures. By ordinary conditions are meant sewers of modern construction, well laid with good gradients, and comparatively free from deposits, the result of stagnation.

Several observers have shown that sewer air may even possess a relatively less number of microbes, capable of forming colonies on cultivation, than the atmospheric air outside; and Mr. Parry Laws' investigations tend to prove that the microbes in sewer air are derived from the organisms usually present in atmospheric air, and are not identical with those usually found in sewage. The microbes in sewer air are chiefly moulds, whilst those in sewage belong to the class of bacilli (see p. 153). The explanation appears to be that the internal walls of sewers are more or less wet or moist, and it is assumed, probably with reason, that the microbes in the sewer air adhere to the damp surfaces, and are thus prevented from floating in the air. This reasoning is strengthened by what is already known of the presence of microbes in atmospheric air generally; for in dry dusty weather they are found in far larger numbers than in damp weather or after rainfall. In well-made sewers the sewage is borne away from the houses in a fresh and undecomposed condition; but in

old and defective sewers, and even in moderately good ones when the temperature of the air is high, and the amount of diluting water is small—as during hot and dry summers—putrefactive bacteria undergo enormous multiplication, fermentative changes are set up in the sewage, and gases are formed which bubble up and break upon the surface of the liquid.

It was demonstrated as long ago as 1871 by Professor Frankland, that liquids flowing smoothly in channels give off no solid particles to the air, and that even considerable agitation resulting in frothing may not cause any perceptible increase of the solid particles in the superincumbent air, but that the bursting of bubbles of gas in a liquid had a marked effect in disseminating solid particles. These experiments have been repeated and extended by subsequent observers, and there can be little doubt but that, given stagnation and putrefaction of sewage and defective sewer ventilation, sewer air will contain an abundance of micro-organisms of different kinds. The experiments of Haldane and Carnelly, which have been recently made, also show that splashing in a sewer, which may be caused by branch drains entering near the crown of the sewer, is productive of dissemination of micro-organisms in the air.

From the above results it might be inferred that sewer or drain air is only likely to be injurious when the contained sewage is undergoing putrefaction, and that, as a foul odour is the invariable accompaniment of putridity, offensiveness is a sufficient criterion of possible danger to health. On this point, practical experience to a certain extent supports such theoretical reasoning; towns which have adopted improved sewerage have lowered their death-rates, especially the enteric fever and diarrhœa mortality. But it must be remembered

that the *quantity* of bacterial organisms—of which the vast proportion are harmless—is no index of the *quality*. Under certain unknown conditions, sewer air is dangerous to breathe whether derived from fresh or putrid sewage, and the assumption that sewer air is harmless because it may contain but few *demonstrable* organisms—and those not of the species commonly present in sewage itself—is utterly unwarranted. All we can assume is that there is, *a priori*, a greater probability of noxious germs being present when the total number is large than when it is small.

The effects on health produced by the inhalation of the products of decomposition of the animal and vegetable organic matters contained in drains, cesspools, and sewers, are various. Occasionally, as when choked drains or foul cesspools and privies have been opened and cleaned out, acute mephitic poisoning has resulted, the symptoms being sudden and violent vomiting, purging, and headache, followed by acute prostration, sometimes fatal. Amongst the Paris scavengers who empty cesspools, partial asphyxia appears not to be uncommon, and is probably due to the excessive amount of sulphuretted hydrogen disengaged when the contents of the cesspools are stirred up, and the very low proportionate volume of oxygen.

As a rule, the injurious effects of drain and sewer air may be attributed to the organic matters with which it is so often laden. This is especially the case when people are exposed to escapes of drain or sewer air into houses for a long period. The dose of the poison may not be sufficiently great at any one time to cause the acute symptoms above described; but the long-continued inhalation of diluted sewer air tends to produce a general loss of health (especially in children), which is shown in various

ways, as by anæmia, loss of appetite, prostration, diarrhœa, fever, headache, vomiting, and sore throat, one or more of these symptoms being usually more prominent than the rest; or it may be that only a condition of depressed vitality is produced, which offers but slight resistance to attacks of acute disease.

Occasionally a severe form of tonsillitis attacks the occupants of a badly drained house. This form of tonsillitis, which is now generally recognised as "sewer air throat," is marked by great inflammatory swelling of the tonsils, very foul tongue, and gastric derangement, accompanied by severe headache and intense depression. The temperature of the body is often not much raised, certainly not to a height proportionate to the severe symptoms; and this low temperature, together with the intense prostration, are characteristic of many illnesses resulting from the entrance of sewer-polluted air or water into the system. Symptoms of blood-poisoning, as shown by petechial rashes, glandular enlargements, lymphangitis, albuminuria, and fever, have been noted by some observers, and attributed to long-continued exposure to drain or sewer air escapes into houses. To what particular constituents of sewer air we are to attribute these and allied illnesses, it is difficult to determine. The attacks of tonsillitis, diarrhœa, etc., are not protective from future attacks; and although there is some evidence of the "sewer-air throat" being contagious and directly transmissible from person to person, it is equally likely that examples of apparently direct contagion are really due to exposure to a common cause.

Inquiries have from time to time been made into the health of sewer men, who are constantly engaged in flushing and removing deposits from sewers. The

results of such investigations lead rather to the belief that the constant breathing of sewer air is not injurious to health and life. But it must be remembered that these are picked men in the prime of life, who, now at any rate, generally work in well-ventilated sewers, where the air is not abnormally foul, and that these inquiries have not been very exhaustive. It appears, too, that they suffer somewhat from ophthalmia, and that the occupation tends greatly to aggravate venereal disease. The work is certainly unsuited to some constitutions, as many men are obliged to give it up after a short trial.

It seems only fair to assume now, in the light of our present knowledge, that the men engaged in this occupation undergo a species of preventive inoculation, or acclimatization, so to speak, to the influences to which they are exposed. The long-continued inhalation or ingestion of a germ-tainted air may be considered as conferring immunity upon the individual so occupied from diseases bred by sewer air, which would readily attack one whose system had not been exposed to the acclimatizing process. Such an occurrence offers a specious explanation of the good health and freedom from infectious disease enjoyed by sewer men and scavengers generally.

Diarrhœa and dysentery are sometimes caused by breathing air contaminated with excretal emanations. This, indeed, seems to be one of the chief causes of the summer diarrhœa which is so common in a hot and dry season in the badly drained districts of large towns. In the case of Leicester, which for many years has recorded a summer diarrhœa mortality exceeding that of any other large town, the late Dr. Tomkins, Medical Officer of Health of the Borough, has shown that soon after the temperature of the earth, at a depth of 1 foot, has

reached 59° F. to 62° F. the causes producing the disease begin to operate. In the low-lying districts of the town the sewers are foul, the solids of the sewage are deposited in the sewers, while the liquids percolate through the sewer walls into the surrounding soil. This polluted condition of the soil Dr. Tomkins regarded as eminently favourable to the development of bacterial forms of life, when the temperature reaches a certain point (59° to 62°); for the disease appears annually when the earth temperature reaches this point, and declines as the temperature declines. He also found that in those districts of the borough where diarrhœa is most prevalent, the air is most contaminated with microbes or their germs or spores, and that these same microbes, when artificially cultivated, possess the power of inducing diarrhœa in the human subject. The low-lying position of the town, which was until lately liable to periodical flooding by the river, helps to intensify the results (see Chapter IX., "Diarrhœa").

There is now being accumulated a very considerable body of evidence to show that puerperal fever may be produced by sewer or drain emanations finding their way into the chamber of a lying-in woman. Erysipelas, pyæmia, septicæmia, and hospital gangrene, if not caused by such emanations, are certainly favoured by conditions of excretally polluted air.

The possibility of enteric fever being caused by inhaling specifically infected sewer air is now the subject of dispute. Certainly the more frequent mode of origin is the drinking of specifically polluted water. Outbreaks of the fever, however, have been recorded in many instances where the water was not at fault, where the passage of infected sewer or cesspool air into houses was a proved possibility, and was the only apparent means by which

healthy people could have been brought in contact with contagion. The evidence as to the spread of cholera by such means is of a similar nature.

When excretal or other offensive emanations are given off into the open air, they are much less liable to cause disease or injury to health than when they find their way into confined spaces, such as narrow courts or the interior of houses. In the open air of the country they are rapidly diluted and oxidized, and rendered practically harmless. In this way we can account for the excellent health enjoyed by the workmen on sewage farms, and by those who live in the neighbourhood, as well as by the men engaged at sewage works. Grossly polluted rivers, which give rise during hot weather to most offensive emanations, have not yet been proved to cause injury to health by such means alone. The same may be said of effluvia from manure manufactories, soap works, tallow works, and other offensive trades, and also of the effluvia from putrefying animal bodies, given off into the open air. The air of crowded graveyards and vaults contains excess of CO_2 and organic vapours (carbo-ammoniacal); if such polluted air rises from the soil and escapes into houses built on disused burial sites, it may cause serious sickness among the occupants; but when the vapours escape into the open air, even in the midst of towns, no marked injurious effects appear to arise.

The air over marshes is impure from the large amount of decaying vegetation in the water and soil. Carbonic acid, sulphuretted hydrogen, and carburetted hydrogen (marsh gas), are generally present in some excess, together with decaying organic matter, both in the form of vapour and of suspended matters. In some marshes the air is very rich in H_2S, and the symptoms of anæmia and prostration have been thought to be due to this fact.

The suspended matters in marsh air consist of vegetable débris, diatoms, algæ, fungi, bacteria, and other micro-organisms.

Vitiation of Air in Industrial Occupations.

Although in some trade processes injurious *gases* are evolved and escape into the air that must be respired by the workmen engaged in the trade, yet the vast majority of industrial occupations are injurious, or otherwise, according to the amount and nature of the *dust* which is produced. As subsidiary factors of high importance must be considered the conditions under which the dust-producing work is carried on, whether in the open air, in well-ventilated workshops or factories, or in overcrowded close rooms at a high temperature and with the air saturated with moisture. The long-continued inhalation of dust tends to produce disease of the lungs, especially bronchitis and emphysema, interstitial pneumonia, and fibroid phthisis. The source of the dust, whether vegetable or mineral, is not so important as the character of the particles which compose it. The most injurious kinds are those whose particles are hard, sharp, and angular, which become impacted in the walls of the bronchioles or air cells of the lungs, are not easily expectorated, and set up irritation and chronic inflammation of the tissues around. The soft or rounded particles are not capable of doing nearly so much mischief.

The following table gives the comparative mortality figures for males in different dust-inhaling occupations, the comparative mortality figure from all causes amongst males in England and Wales being taken at 1,000, 220 of which are due to tubercular phthisis, and 182 to other diseases of the respiratory organs. It is important to note that the column under phthisis represents the

tubercular form of this disease, but undoubtedly includes many cases of fibroid phthisis as well.

Comparative Mortality of Males, Twenty-five to Sixty-five Years of Age, in certain Dust-inhaling Occupations, from Phthisis and Diseases of the Respiratory Organs.*

	Phthisis.	Diseases of the Respiratory Organs.	Phthisis and Diseases of the Respiratory Organs.
Coal-miner	126	202	328
Carpenter, joiner	204	133	337
Baker, confectioner	212	186	398
Plumber, painter, glazier ..	246	185	431
Mason, builder, bricklayer ..	252	201	453
Wool manufacturer	257	205	462
Cotton manufacturer ..	272	271	543
Quarryman (stone, slate) ..	308	274	582
Cutler	371	389	760
File-maker	433	350	783
Earthenware manufacturer ..	473	645	1,118
Cornish miner	690	458	1,148
All males (England and Wales)	220	182	402
Fishermen	108	90	198

That *coal-miners* should stand at the head of the list, as regards freedom from lung diseases, is somewhat surprising, considering that the air in the underground passages in which they work, even in the best-ventilated mines, is vitiated by respiration, combustion of lights, and blasting agents, which throw into the air much CO_2, CO, H_2, H_2S, etc. In addition, CO_2 and CH_4 are often evolved in considerable volumes from the strata cut through by the shafts and borings, and the air in the workings is always thick with coal dust. Dr. Ogle

* Dr. Ogle's Report, Supplement to the 45th Annual Report of the Registrar-General.

explains the comparative innocuity of coal dust in causing lung disease by the microscopical character of its particles, which are comparatively free from sharp points and corners. He is also inclined to attribute to coal dust a special property of hindering the development and arresting the progress of tuberculosis—a disease, it is to be remembered, which might be expected to be very fatal to coal-miners, from the fact of their working in a heated vitiated atmosphere, and being liable to sudden alterations of temperature in going to and leaving off work.

This comparative immunity from tubercle is not displayed by the *Cornish* or *tin-miners*, who come at the bottom of the list. Their mortality from lung diseases constitutes nearly two-thirds of their total mortality, and is nearly three times as great as that of Cornish males generally. They work under conditions of heated and vitiated air like the coal-miners, but they inhale a sharp, angular, and most irritant stone dust, instead of the comparatively benign coal dust. The other occupations in which the workers are exposed to the inhalations of stone dust are *masons*, *builders*, and *bricklayers*, who carry on their work chiefly in the open air, and have a lung disease figure of 453; *stone* and *slate quarrymen*, who also work mainly in the open air (582); and the *earthenware*, *china*, and *pottery manufacturers*, who suffer enormously from bronchitis and emphysema (potters' asthma), and phthisis. Among these latter the lung disease mortality is nearly the same as that of the tin-miners. They carry on their trade in close and heated factories, and, besides the fine irritating dust, are exposed to great vicissitudes of temperature. The chinaware is baked with flint dust, and this is subsequently brushed off by women, the process being known as "china scouring." In the

best factories this dust is collected and removed by mechanical brushes and fans, and is never allowed to escape into the room.

Cutlers and *file-makers*, *needle*, *pin*, and *tool makers* are exposed to metallic dust and stone dust given off from the grindstones, and suffer largely from phthisis, bronchitis, and pneumonia. File-makers are in addition liable to lead-poisoning, from their using a cushion of lead on which to strike their file. The operatives in *cotton factories* work in a heated atmosphere saturated with moisture by steam, and laden with filamentous particles of cotton and mineral substances used for sizing. A standard of purity of the air is now enforced, by which the CO_2 may not exceed 0·09 per cent., and an artificial humidity of the air has to be maintained by means of steam. In *woollen factories* the heat is not so great, and there is less dust owing to the wool being treated with oil; but wool-sorters are liable to contract anthrax from infected fleeces. In *silk-mills*, dust and high temperature are injurious to the material, and are consequently avoided.

Millers and *bakers* are liable to inhale flour dust, but as this substance is probably arrested in the mouth and nose, and does not reach the lungs, it can hardly be regarded as productive of lung disease. *Carpenters*, *joiners*, and *cabinet-makers* are exposed to wood dust. The dust from the harder kinds of wood is probably more injurious than that from the softer kinds.

Printers, *earthenware manufacturers*, *plumbers*, *painters*, *glaziers*, and *file-makers*, are all subject to lead-poisoning. Plumbers inhale volatilized oxide of lead, and painters the dust of white lead; but lead is also taken into the system when meals are eaten with dirty hands. Gout, renal disease, and diseases of the heart and brain, are

also common in these trades, and are the sequelæ to a large extent of the lead-poisoning.

More recently Dr. Tatham has furnished a valuable contribution* on the varying rates of mortality among men engaged in different occupations, the main conclusions being based upon the deaths that occurred during the three years 1890-92 among males between twenty-five and sixty-five years of age — the period during which the effect of occupation is assumed to be most marked, and in which the proportion of occupied males is largest. Taking 1,000 to represent the mortality of all males at these ages in England and Wales, the comparative mortality figure for all *occupied* males was 953, and while it was but 687 in agricultural districts, it reached to 1,248 in industrial districts. The comparative mortality figures of males from twenty-five to sixty-five years of age was low for clergymen (533), gardeners (553), farmers (563), school-teachers (604), farm-labourers (632), and lawyers (821); for medical men it was 966; and it was high among brewers (1,427), general labourers in industrial districts (1,509), publicans (1,642), costermongers (1,652), and hotel servants (1,725). The excessive mortality of cutlers, file-makers, scissor-makers, and nail-makers, noted in previous periods of observation, was still higher in 1890-92; and slaters, tilers, wool, silk, and cotton dyers, potters, glass manufacturers, tin-miners, coal-heavers, and chimney-sweepers again showed marked excess of mortality.

In Dr. Tatham's report the figures bearing upon the fatal effects of breathing dust-laden air, or air fouled in other ways, have acquired increased value from the careful elimination of the disturbing influence of the varying age proportions of persons engaged in different

* Supplement to the 55th Annual Report of the Registrar-General.

occupations. Taking 100 to represent the combined mortality from phthisis and diseases of the respiratory organs among those engaged in agricultural occupations, the comparative figure from these diseases among those engaged in occupations which cause dust of various kinds reaches 373 for file-makers, 407 for cutlers and scissor-makers, and 453 for potters and earthenware manufacturers.

Other trades which give rise to dust or injurious fumes are: The manufacture of arsenical wall-papers and artificial flowers, causing a dust which irritates the skin of the exposed parts and induces a rash, and on inhalation may produce symptoms of arsenical poisoning; chemical works producing sulphuretted hydrogen gas in large quantities; cotton and worsted bleaching works where sulphurous acid is given off, causing occasionally bronchitis and anæmia; alkali works giving off hydrochloric acid vapours; vulcanized india-rubber works producing bisulphide of carbon; and cement works and brickfields, where organic vapours and CO_2, CO, H_2S, SO_2 gases are evolved. In the manufacture of Portland cement traces of compounds of cyanogen are given off during the process of burning.

Brickfields are most productive of nuisance when the bricks are burnt in clamps or quadrangular piles in the open air, and the combustible material used is dust-bin refuse containing animal or vegetable organic matter. Bricks are made of clay mixed with a small proportion of ashes. When these are arranged in layers in the clamps, alternating with the breeze or combustible material, the emanations from the burning material are very penetrating; and when dust-bin refuse is used to burn the bricks, the partially burnt organic vapours are highly disagreeable, and are perceptible at considerable

distances from the brickfields. When bricks are burnt in kilns provided with flues, there is far less liability to nuisance, as the products of combustion are more perfectly consumed. Kiln burning should be insisted upon in the case of all brickfields situated in the close vicinity of inhabited houses.

In brass foundries the workers (more especially the turners, polishers, and filers) inhale a metallic dust which is productive of a disease until lately known as "brass founders' ague." But Dr. R. M. Simon has shown that brass workers' ague is not ague at all, and is not in any way allied to malarial poisoning. The symptoms which caused Dr. Greenhow to designate the disease brass workers' ague are shown to be due to the ingestion of a quantity of the irritant metal dust (brass is an alloy of copper and zinc, in the proportion of about three to one) sufficiently large to cause vomiting with its attendant depression. The illness only occurs in those who are new to the work, or who resume work after an absence of a month, or even a fortnight, and there are no true hot or sweating stages as in true ague, although at times there may be profuse sweatings. The men who suffer in this way drink freely of milk and promote vomiting, the best treatment that could be devised for copper or zinc poisoning. Chronic copper-poisoning is common amongst brass workers, and bronchitis from inhalation of irritant dust. The leading symptoms of chronic copper poisoning are: Anæmia, nausea and vomiting, colic, wasting, headache and nervous symptoms, and a green line (due to copper) is seen at the bases of the teeth.

In the manufacture of bichromate of potash a dust is inhaled which causes nasal ulceration. Match-makers, who make the "strike-everywhere" match with yellow

phosphorus, suffer from necrosis of the jaw, the result of exposure to the phosphorus fumes; and silverers and gilders, who worked with amalgams of gold and silver with mercury, were formerly the subjects of mercurial poisoning, until electro-plating by electrolysis replaced the older methods.

Two other occupations may be mentioned in which workers are exposed to carbonic acid gas inhalation. These are well-sinkers, who are occasionally asphyxiated by the large amount of this gas which is evolved from the soil, and collects in deep shafts; and soda-water manufacturers. In this latter occupation, however, the CO_2 is never present in the air in sufficient quantity to cause injury to health or life.

The Alkali Works, etc., Regulation Act of 1881 provides that 95 per cent. of the hydrochloric acid gases and vapours produced in alkali works must be condensed; and in each cubic foot of air, gas, or smoke escaping into the atmosphere there may be only $\frac{1}{5}$ grain of HCl. Each cubic foot of air, gas, or smoke issuing from sulphuric acid works must not contain more than 4 grains of sulphuric acid (SO_3). The keeping apart of acid drainage and alkali waste is strictly enforced, and all waste substances must be got rid of without nuisance. Other works included in this Act are salt works, cement works, chemical manure works, nitric acid works, sulphate and chloride of ammonia works, chlorine works, bleaching works, and gas liquor works.

In the manufacture of alkali the chief nuisance arises from the improper storage and disposal of the "tank waste," which contains compounds of sulphur. In the process, common salt is decomposed by sulphuric acid, and the crude sodium sulphate ("salt cake") is mixed with chalk and coal and heated; sodium carbonate is

thus formed, and the unburnt carbon and calcium sulphide darkens the mass, which is known as "black ash." The sodium carbonate is dissolved out by water, and the residue constitutes the "tank waste." The workers suffer from diseases of the lungs, bad teeth, and dyspepsia, mainly arising from the acid fumes of the salt cake; but the hydrochloric acid fumes are so diluted as to generally produce but little effect on the workers, though they injure surrounding vegetation.

In the manufacture of coal gas, the coal is burnt in closed retorts, with the result that the coke remains behind, and the volatile substances pass up an ascension pipe to discharge into horizontal pipes exposed to the air, in which the watery and tarry matters are condensed. The impure gas is then passed through coke scrubbers, which remove the remaining tarry matters and ammonia. All this condensed matter is conducted into the tar well. The sulphur compounds which remain in the gas at this stage are partially removed by passing the gas over lime, which also removes the carbonic acid, and the remaining sulphuretted hydrogen is removed by a purifier of oxide of iron. The gas is stored in the gasometers, which are sunk in the earth to considerable depths, water being used as a seal to prevent the escape of the gas.

The process varies somewhat in different manufactories. The waste gas-lime gives rise to serious offence, and its removal from the tank causes considerable irritation to those engaged in the work. The lime should be watered a little before being dug out from the purifiers, to prevent dust; and removed as often as necessary, being covered over with sacking during removal.

Nuisance may result in the neighbourhood of gas-works by (1) smoke given off during the charging and drawing of retorts; (2) the generation of water gas when

the red-hot coke is quenched with water; (3) the escape of crude gas from the mouthpieces of the retorts; (4) the smoke given off from imperfectly carbonized charges when withdrawn; (5) by the offensive lime refuse from the purifiers, where lime alone is used for the absorption both of carbonic acid and sulphur compounds. When exposed to the air, sulphuretted hydrogen and bisulphide of carbon are released from the sulphides and sulpho-carbonates of lime by the action of the oxygen and carbonic acid in the air, and a most offensive nuisance is created. When, however, sesquioxide of iron is used for absorbing the sulphur compounds, and the lime is used only for absorbing carbonic acid after the sulphur compounds are withdrawn, the nuisance is reduced to a minimum.

Offensive Trades.

The noxious or offensive trades specified in the Public Health Act, 1875, are those of a blood-boiler, a bone-boiler, a tripe-boiler, a soap-boiler, a tallow-melter, and a fellmonger. Bye-laws may be made regulating these trades "or any other noxious or offensive trade." The model bye-laws of the Local Government Board also specify the trades of a blood-dryer, a leather-dresser, a tanner, a fat-melter or fat-extractor, a glue and size maker, and a gut-scraper. As to what will constitute "a noxious or offensive trade" other than those specified, it is held that the business, in addition to being proved noxious, must be *ejusdem generis* with those specified, and deal with animal matters in some form. Thus, brick-making has been held not to be "an offensive trade," whereas the business of a rag-and-bone merchant is so.

A BLOOD-BOILER or BLOOD-DRYER deals with the fresh blood collected at slaughter-houses, in order to procure

(1) blood albumin, by desiccating the serum which is drained off from the clots, (2) turkey-red pigment; and he may also (3) prepare blood for sugar refiners, etc. The blood-clot is often mixed with sulphuric acid, desiccated, and mixed with superphosphate to form manure.

The chief sources of nuisance are: (1) Unsuitability of premises for carrying on the process, thus rendering it difficult to conduct the business without nuisance; (2) the improper conveyance and storage of the blood; (3) offensive vapours given off during the process of blood boiling or drying, or manure-making (which is often carried on on the same premises); (4) effluvia from the storage of exhausted clots prior to the manufacture of manure or their removal from the premises.

A BONE-BOILER deals with fresh bones in order to procure gelatine, glue, and fat. The bones are boiled along with the hoofs, trimmings of hide, etc., procured from the slaughter-houses. The boiled bones are subsequently used for handles to knives and forks, tooth-brushes, etc., or are crushed, and superphosphate manure manufactured from them by adding sulphuric acid.

The chief sources of nuisance arise from: (1) Unsuitability of premises; (2) improper conveyance and storage of old bones and scraps; (3) offensive vapours given off during the process, especially where steam-jacketed cylinders are not used for the boiling; (4) the débris in the boiling cylinder, called "the scrutch," is a fruitful source of nuisance, as is also the piling up of the recently boiled and steaming bones.

A TRIPE-BOILER is one who boils the first stomach ("the paunch") of oxen and sheep for sale as food.

The chief nuisances result from: (1) Filthiness and unsuitability of premises; (2) improper storage of material on premises; (3) the vapours escaping during the process

of boiling; (4) the vapours arising from the steaming tripe after its removal from the boiler.

A FAT OR TALLOW MELTER (and SOAP-BOILER) is one who melts kitchen fat and butchers' waste fat in pans for the purposes of manufacturing candles, soaps, leather dressings, and preparations for greasing machinery. In soap-boiling the fat is boiled with soda-lye for "hard soaps," and with potash-lye for "soft-soaps."

The chief nuisances result from: (1) Filthiness and unsuitability of premises; (2) improper conveyance and storage of material; (3) the vapours escaping during the process of melting or boiling and ladling out; (4) the improper stowage of waste residue ("the greaves"). The greatest nuisance during melting arises when old and offensive materials are used.

A FELLMONGER is one who prepares either recent or old foreign skins for the leather-dresser. The fresh skins are first trimmed of adherent flesh and then freed from dirt by beating them with sticks. They are then soaked in water. Lime is next worked into the fleshy side of the skin, and the skin is then hung up until the wool or hair is easily detachable by the hand. The old foreign skins are prepared by first soaking in water, and then they are kept until decomposition has so loosened the wool or hair that it is easily detached; this is known as "the tainting process." By either method the skin thus prepared is known as "a pelt," and these are cast into a pit containing milk of lime, after which they are dried and sent to the leather-dresser.

The chief nuisances arise from: (1) Filthiness and unsuitability of premises; (2) improper conveyance and storage of skins; (3) offence arising from the "tainting" process; (4) the failure to satisfactorily dispose of the dirt and flesh removed from the skins.

A LEATHER-DRESSER and TANNER convert the skins, after treatment as above described, into various kinds of leather. The tanning agent (oak-bark, etc.) brings the putrescible hide into a non-putrescible condition; and the leather-dresser, by appropriate treatment with fatty and other matters, completes the conversion to leathers of various sorts. Pigeons' manure and dogs' dung are used in the "soaks" for softening the skins prior to tanning.

The chief nuisances arise from: (1) Filthiness and unsuitability of premises; (2) improper storage of skins; (3) the failure to satisfactorily dispose of the waste water or spent liquor, etc.

A GUT-SCRAPER is one who scrapes the small intestines of swine and sheep for the purpose of making sausage-skins, catgut, etc. The gut is first cleansed, and soaked in salt and water for a few days, and then allowed to remain in plain cold water until sufficiently softened to admit of the easy removal, by means of a wedge-shaped piece of wood, of everything but the peritoneal and a little of the external muscular coat of the intestine.

The chief nuisances arise from: (1) Filthiness and unsuitability of premises; (2) the failure to promptly remove all refuse and waste material; (3) improper and too prolonged storage of the intestines prior to their utilization.

A GLUE AND SIZE MAKER extracts the gelatine by boiling almost every kind of waste animal tissue, but more especially bones, hoofs, horns, and skin-trimmings. The raw material is first limed, and then washed and well boiled for some hours. After the glue has been allowed to cool and set, it is cut into slices and dried.

The chief sources of nuisance are: (1) Unsuitability and general filthiness of premises; (2) the storage of material, especially when old and foul; (3) vapours arising from

the conduct of the process, which are especially offensive when old material is used; (4) the accumulation and improper storage of the residue ("scrutch"). The fat is usually skimmed off the surface of the hot water, and the "scrutch" is used for manure-making.

The various nuisances in the trades above referred to may be prevented or abated by the adoption and enforcement of sufficient bye-laws.

Such bye-laws should secure—

1. Free access to the premises by any officer of the sanitary authority.

2. The restriction of such trades to suitable premises. Gut-scraping, for instance, cannot be carried on, as it sometimes is, in small houses without giving rise to offence.

3. The maintenance in good order of the drainage, lighting, and ventilation of such premises, and the proper cleansing of them. The floors or pavements should be kept in good repair so as to prevent absorption of any liquid filth, and should be swept or washed at the close of every day, and all splashings should be removed. The walls and ceilings should be hot lime-washed twice a year at specified periods (say the first weeks of April and October), after all splashings have been wiped off; and the walls must be rendered non-absorbent of any liquid filth or refuse to at least the height to which such splashings may reach.

4. The proper conveyance to the premises, and storage on the premises, of the material used, so as to prevent the escape of noxious and offensive emanations. In some cases the material should be brought to the premises in non-absorbent covered receptacles, and stored in special closed compartments ventilated into a tall chimney flue,

by means of an air-shaft provided, if necessary, with a gas-jet or fan. Sometimes the materials to be stored should be dried, or treated with milk of lime, or even sprinkled with a little carbolic acid solution (1 in 40). Stored fat should be dried and laid out on racks in a cool room; and the materials used for glue-making should be stored as dry as practicable, or treated with a sufficient quantity of milk of lime and closely stacked.

5. The best practical means of rendering inert the vapours emitted during the carrying on of the process. Where melting and boiling is performed, this should be done in steam-jacketed pans, so as to guard against the higher temperatures which burn the fat, etc., and give rise to the formation of most offensive empyreumatic odours. Large hoods communicating by pipes with the furnace-flue should be used to collect the vapours given off from the contents of the pans during the boiling; and the chimney by which these fumes escape should either be carried up to a considerable height, or the vapours should be condensed in a suitable condensing apparatus,* or conducted into the furnace fire and cremated. This cremation may also be effected by means of a small "cremator" placed in the chimney.

The fumes arising from steaming bones, meat, etc., can be prevented by applying cold water directly after the removal of the latter from the boiler.

6. All filth and refuse matter to be collected in a sufficient number of non-absorbent vessels with close-fitting covers, and removed from the premises forthwith. Fell-

* A cheap and satisfactory condenser can be made by taking ordinary drain pipes and packing these with pieces of coke, over which water is allowed to trickle in a constant stream; or the vapours may be absorbed in a water-spray, or by being brought in contact with trays of water, as in a "scrubber."

mongers and others must not keep uselessly decomposed skins, etc., on the premises.

7. All water used for soaking skins, etc., to be renewed sufficiently often (at least once a day) to prevent effluvia arising therefrom, and all pits used for holding such water to be rendered water-tight. This bye-law will apply to the trades of a fellmonger, gut-scraper, and leather-dresser.

8. All waste lime to be removed with reasonable dispatch in covered receptacles, as also all other waste or useless material.

9. All implements and receptacles to be kept sweet and clean. The floors and receptacles in some cases to be sprinkled or washed with some deodorant, as in gut-scraping.

10. Penalties for offending.

The discharge of waste liquor into drains at a temperature exceeding 110° F. has often given rise to great offence from the sewer ventilators adjoining the premises on which some of the above trades are conducted. This is now prohibited by statute (The Public Health Act Amendment Act, 1890), and all hot liquid refuse must be allowed to cool before it is discharged into a drain.

It will be well to next consider a few of the more common *trade nuisances*.

Fish-frying.—Nuisances arise from the neglect to adopt proper means of collecting the effluvia and dealing efficiently with them. The effluvia are increased by (1) the prolonged use of the same oil for cooking purposes, (2) the burning of the oil and consequent production of empyreumatic odours, when the heating is done over an open fire.

These nuisances are best prevented by supplying a

large deep hood to collect the effluvia arising from the frying. The hood should lead by a pipe into a fairly high chimney, and it is often necessary to provide a gas-jet at the mouth of the pipe leading from the hood, so as to promote draught. To obviate the burning of the oil, the frying should be done in a deep vessel containing from 6 to 10 inches in depth of oil, or preferably steam-jacketed cylinders should be employed. It is rarely, if ever, necessary to cremate the effluvia in the fire, or to absorb them in the water of a "washer" or condenser.

KNACKERIES.—A knacker is properly a horse-slaughterer, but he also slaughters other old and diseased animals, and receives the carcases of those which have died of disease or accident.

Nuisances arise from the cries of the animals prior to their slaughter, for they are commonly kept several days; the filthy way in which they are kept; the undue and improper storage of material on the premises; the general unsuitability and filthiness of the premises; and the processes of bone-boiling, flesh-boiling (for cats' meat or fat extraction), or gut-scraping, etc., which are sometimes carried on in the same premises.

PIG-KEEPING.—This trade may become a nuisance from the improper storage of sour, malodorous food with which the pigs are frequently fed, and from the effluvia from the sties. The sties should always be placed at a considerable distance from houses—at least 100 feet in urban districts. They should be floored with hard, impervious, and jointless material (*e.g.*, concrete), laid to a good fall towards a channel leading to a gully which discharges into a drain or a covered cesspool. The feeding material should be kept in impervious vessels with close-fitting lids, and the sties should be swept out and cleansed daily.

Artificial - manure - making. — The materials used are: (1) All animal waste materials from the offensive trades above referred to; (2) mineral matter, *e.g.*, sulphate of ammonia, nitrate of soda, gypsum, etc.

"Superphosphate" is made from a mixture of mineral phosphate and ground bones, treated with sulphuric acid. The whole process is more or less offensive from the presence of the organic materials, and the fumes given off during the manufacture and the subsequent drying.

"Poudrette" is generally manufactured from night-soil, fish offal, etc., by treatment with sulphuric acid; it consists of a brown dry powder. The process must be conducted under very special conditions, or a grave nuisance results.

Paper-making.—Cotton and linen rags, hemp, straw, waste paper, etc., and esparto grass, are employed in this business. The rags are "dusted," and then cut up into small pieces, washed, and bleached.

Esparto grass is reduced to pulp by boiling with caustic alkali and by subsequent treatment by machinery.

The vapours given off during the boiling of the grass, and from the hot liquor after removal from the boilers, have an offensive senna-like odour, but the recovery of the soda from the waste liquor is the most offensive part of the process.

Industrial Poisonings.

Lead-poisoning may result from direct absorption of the metal through the skin or mucous membranes, or by inhalation of the vapours or powder of lead compounds. The trades most liable to suffer are: painters, gilders, file-cutters, type-founders, calico-printers, colour-grinders, glass-grinders, bronzers, and enamellers.

Carbonate of lead, or white lead, is very extensively used as a paint, and many coloured paints contain the metal. Both the acetate and the nitrate of lead are used in calico-printing and cotton-dyeing to produce orange and yellow colours. Sulphide of lead is used mainly for glazing pottery, bricks, etc., and oxide of lead is used in enamels.

File-makers are liable to lead-poisoning from their using a cushion of lead on which to rest the file, while the rough surface is being prepared by means of a blunt chisel struck with a hammer. The glass-grinders may be poisoned from the constant contact with the fine glass-powder, which is rich in lead; and the type-founders and type-setters from the constant handling of the type-metal—an alloy of lead, tin, and antimony.

At present the most common causes of lead-poisoning are the working with lead glazes, and the manufacture of white lead.

Sanitary Precautions.—1. All fumes and dust should be collected as rapidly and completely as possible after they are formed, and conducted, by means of a powerful exhaust, to condensing chambers or washers, so that the air of the work-places may be kept as pure as possible, and the external atmosphere around the works also saved from pollution.

2. The handling of the metal, or of substances containing lead, should be reduced to a minimum.

3. Every facility and encouragement should be given to the workers to practise personal cleanliness. Mouth-washes and tooth and nail brushes should be used before partaking of a meal. Strict rules should be enforced for the washing of hands. A basin, tap, and towels must be supplied for at most every five persons.

4. In the more dusty rooms overalls, close fitting

round the neck and wrists, and respirators, are desirable; and exhaust-fans should be used to remove dust and to insure abundance of fresh air.

5. Meals should not be permitted to be taken in any of the workrooms.

6. There should be periodical medical inspections of the workers. Those who are more especially susceptible to the poisonous effects of the metal should at least be excluded from the more dangerous rooms. This will apply to all women and children. All those with cuts or sores should be excluded from the works.

7. Sulphuric acid lemonade is recommended as a drink for the work-people, as it favours the formation of an insoluble sulphate of lead; the free drinking of milk is also recommended.

8. The workrooms must be kept clean, well ventilated, and as free from dust as possible.

The beautiful glaze on chinaware and its colouring have hitherto been mostly obtained by the use of carbonate of lead, and the workers in these processes suffer considerably from lead-poisoning. The use of "fritted" lead—that is, lead fused into a kind of glass (a silicate) which is ground down and mixed with water—is attended with far less danger to the workers. It is stated that it is even safer to employ a double silicate of lead, which is more insoluble than the silicate. It appears, moreover, that the use of leadless glazes gives equally satisfactory results in ordinary white and cream-coloured ware; and experts have expressed the view that for seven-tenths of the total output leadless glazes can be used.

Phosphorus-poisoning is experienced among match-makers. The phosphorus is obtained from bone ash, and serious nuisance and harm to the workers will result unless every proper precaution is taken. During the

distillation of the impure phosphorus dangerous gases are evolved.

The red or amorphous phosphorus is largely used in the manufacture of safety matches, the phosphorus mixed with glue being contained in the rubbing surface on the box. The igniting material is composed of chlorate of potash, iron pyrites, peroxide of manganese, powdered glass, sulphide of antimony, and an adhesive agent—generally glue.

Sanitary Precautions.—1. The discontinuance of the use of the dangerous yellow phosphorus, and the employment of the red phosphorus for safety matches only. A harmless "strike-everywhere" match can now be made from the sesquisulphide of phosphorus.

2. Frequent medical inspection, especially of the teeth. It is found that workers with sound teeth are practically exempt, but workers with carious teeth are specially prone to poisoning by phosphorus and to the onset of "phossy jaw" (caries of the jaw bones).

3. The selection of the workers.

4. Every facility for the practice of extreme personal cleanliness. Alkaline mouth-washes should be used.

5. Large, specially well-ventilated workrooms, and when possible the work should be performed in the open air. This precaution greatly reduces the amount of phosphorus-poisoning.

6. No food or drink to be taken in the workrooms.

7. Short shifts of work, especially of those employed in the more dangerous rooms. Charcoal respirators should be worn by those engaged in the worst rooms; *i.e.*, where the dipping of the wooden heads of the matches in the phosphorus paste is performed.

The oxidizing effect of the vapour of turpentine is recommended as advantageous. The atmosphere may

be impregnated with these vapours by exposing turpentine in saucers about the room, or on sponges hung round the necks of the workers, so that the vapours rise up into the air as it is respired.

The phosphorus should always be stored carefully in glass or earthenware vessels surrounded by water, and away from the workrooms.

The sulphur employed must not be overheated, or there is danger of ignition and the development of large quantities of SO_2. The pans in which the sulphuring is done should be covered, and the fumes conducted to a tall chimney.

By an order of the Secretary of State in March, 1899, cases of phosphorus-poisoning must be notified under Section 29 of the Factory and Workshop Act, 1895.

Mercurial-poisoning.—Those exposed to the poisonous effects of the vapours are mainly the makers and users of vermilion pigment from cinnabar and of imitation bronzing, and the gilders working with mercurial gold amalgam. The former great source of industrial mercurial poisoning — the silvering of mirrors — has ceased, the process having become obsolete.

The sanitary precautions necessary are similar to those already indicated where poisonous fumes and dust occur; but it is important to observe that the mercury should be kept covered over as much as possible, so as to limit the diffusion of the vapours, especially in hot workshops. The diffusion of the vapours of ammonia throughout the workshops, when these are temporarily vacated, is highly spoken of. The floors of the workshops should be such as to admit of a thorough collection of all spilt mercury at the end of each working day.

Arsenic-poisoning may result from the use of arsenical wall-papers, carpets, and curtains, in which the arsenic

is used as a colouring agent. In the following trades the workers are liable to arsenic poisoning : The makers of articles coloured with arsenical dyes (carpets, dresses, artificial flowers, etc.) ; those who prepare skins of animals for stuffing ; and the makers of arsenical paints and dyes, such as emerald green.

The sanitary precautions necessary are very similar to those which should be practised against lead-poisoning. Arsenical colours and dyes are unnecessary, and their use should be prohibited. No water from the works containing waste arsenic should be allowed to enter a stream.

Chromium-poisoning.—Chrome colours are largely used by dyers, chiefly as yellow, orange, and red colouring agents. The chief symptoms of poisoning (from swallowing chromium) closely resemble those of Asiatic cholera. The effect of the chromates of potash on the skin and mucous membranes exposed to their action is to cause destructive ulceration, the nasal mucous membrane being especially liable to suffer from the lodgment of the fine dust resulting from the grinding of the chromates.

The sanitary precautions which are necessary can be gathered from what has already been said with reference to lead.

Sulphurous acid may find its way into the atmosphere from a large number of industries : The manufacture of sulphuric acid, alum, and glass, the tinning of iron, bleaching works of certain kinds (wool, cotton, silk, straw, etc.), the preparation of hops, and the burning of coal rich in pyrites, etc.

Chlorine may gain access to the atmosphere from bleaching and dyeing works. It causes acute catarrh, acute pneumonia, conjunctivitis, pyrosis, and indigestion. Respirators kept moist with alcohol are recommended as a protection.

Carbonic acid is given off in large quantities from lime burning, and is often present in excess in the air of aerated water manufactories.

It causes debility, loss of appetite, drowsiness, and nervous derangements, and when present in great quantities causes dyspnœa, muscular debility, and coma, and if death results the heart and lungs are filled with dark blood.

In carbonic-oxide-poisoning, on the other hand, there is no dyspnœa, coma is slight or absent, convulsions occur, and the blood is bright, with a bluish tint.

Household Dust.

Besides vitiation by products of respiration and combustion, one great cause of impurity of air in houses is the presence of floating particles of dust. This dust is the débris arising from the wear and tear of articles in domestic use, mingled with the soot and ashes from fireplaces, lamps, and gas-burners. As soon as the air is still, it tends to settle upon walls, floors, and articles of furniture, to be again caught up and wafted into the air, when this is in brisk movement. Under the microscope this dust resolves itself into soot, mineral particles (sand, crystals of sodium chloride), cotton fibres, spores of fungi or bacteria, starch grains, pulverized straw, epithelial and epidermic débris from the skin. It is thus seen to consist largely of organic refuse, often more or less putrescent, and its presence in the air assists in the production of the low state of health so common to the occupants of dirty overcrowded houses.

In all houses dust must be produced by the wear and tear of domestic life; but in towns this strictly domestic dust is much augmented by that which finds its way in through doors and windows from the outer atmosphere.

We cannot hope, then, to materially limit its production; but much may be done to get rid of it, and to prevent its undue accumulation, by thorough and regular house-cleaning.

House-cleaning can only be efficient where the structural conditions of walls, floors, and ceilings permit of easy access for the broom and duster into every part of the room, and where furniture and fittings are so arranged as to prevent dust being deposited in inaccessible places.

As generally arranged, nearly every part of a room is a dust-trap. Cornices and projections on ceilings and above doors; rough or flock wall-papers; floors with crevices between the boards into which dust drops, to gradually accumulate between the floor and the ceiling below; carpets accurately fitting every corner of the room; cumbersome articles of furniture, as wardrobes, sideboards, and bookcases, which collect dust above, and are too heavy to be moved to allow dust to be swept out below; heavy curtains with canopies, draperies, etc. —all these tend to the collection or absorption of dust, which, being unseen, is forgotten and not removed.

It is especially in bedrooms, which are occupied for so many hours without any thorough renewal of the air, that these dust absorbers and accumulators tend to do so much harm, by contaminating an atmosphere already sufficiently vitiated. The following rules, therefore, although to be recommended in every room of a house, are more especially applicable to bedrooms.

The floors, if old and warped, should be accurately fitted with thin oak parqueterie, kept well polished with oil and beeswax; or the spaces between the boards may be filleted—*i.e.*, filled in with strips of wood, so as to leave no chinks—and the whole either stained or varnished, or coated with three or four good coats of paint and

varnished. This flooring can be kept clean with a damp duster. Carpets should be abolished in favour of mats or Indian matting for bedrooms, which is very non-absorbent and easily cleaned. The mats can be frequently shaken and beaten in the open air, whereas fixed carpets are usually beaten once a year, and in the interval accumulate (especially the thick pile carpets) every kind of refuse and abomination. The use of linoleum and oilcloth should be avoided, as it hinders the ventilation of the boards, and tends to cause dry rot.

Heavy curtains, canopies, and draperies should be replaced by light muslin fabrics — more especially in bedrooms—which can be washed and cleaned at frequent intervals. Bedroom furniture should be light and easily moved. It would be a great improvement, if, when houses are built, the bedroom walls were planned with recesses, which could be converted into cupboards, shelves, and drawers; and thus the actual furniture of a bedroom could be reduced to the bed, washstand, dressing-table, and chairs, and there would be no surface on which dust could lie concealed.

Cornices and projections from walls and ceilings should be avoided, as likely to collect dust.

The wall coverings should be smooth and glossy. Rough wall-papers, especially flock-paper, can hold enormous quantities of dust. For bedrooms and nurseries, distemper colouring is perhaps better than wall-papers, as the surface can be renewed at a trifling cost and at frequent intervals. In distempering, common whiting is used as a basis for the colouring, and not white lead or zinc white, as is almost invariably the case in painting. Newly painted surfaces give off traces of lead, volatilized or in powder, to the air in drying; and symptoms of lead-poisoning are not uncommon in the occupants of a

freshly-painted room. Painting, then, is not to be recommended for wall surfaces, unless the paints are warranted free from lead. Sometimes the paints themselves contain no lead, but the "dryers," with which they are mixed before use, are found to be full of lead.

Varnished wall-papers are coming more largely into use. They have a smooth, non-absorbent surface, and are easily cleaned with a damp cloth. In papering a room it is important to see that the old paper is all peeled off, and the plaster underneath well washed, before the new paper is applied. The size and paste used should be perfectly fresh.

A paper should never be put on a wall unless it is guaranteed free from arsenic; and it is even advisable to test a piece with Marsh's apparatus to make perfectly certain. The general supposition is that wall-papers are not likely to contain arsenic unless they are coloured some shade of green. But arsenic has been found in various coloured papers—reds, mauves, browns, and grays. The arsenite of copper (Scheele's green) and the aceto-arsenite of copper are principally used in the manufacture of green papers. The amount of arsenic present has been found to vary in different cases from a grain, or less, per square foot up to 50 or 60 grains.

The injurious effects of arsenical wall-papers appear to be due to the dissemination of the vapour of arseniuretted hydrogen, or of solid particles of arsenic, as dust, into the air of the apartment. In flock-papers, coloured with arsenic, it is probably diffused as dust; whilst in the smoother papers arseniuretted hydrogen is formed by the decomposition of the size and paste on a damp wall acting chemically on the arsenical salt.

The long-continued inhalation into the lungs or swallowing of the arsenical dust and vapours derived from

wall-papers tends to produce a chronic form of poisoning, characterized by one or more of the following symptoms, arranged more or less in the order of their appearance, viz., conjunctivitis and lachrymation, cough, nausea, sickness and diarrhœa, colic pains, cramps, dryness of the mouth and throat with much thirst, headache, and gradually increasing debility, with actual paralysis of the extremities, terminating in convulsions and death.

As a rule, the symptoms do not go beyond conjunctivitis, cough, nausea, and diarrhœa, with much debility. But these cases of illness often last for a long period, until, indeed, the source of the poisoning is discovered. The artificial fruit and flower makers suffer from arsenic-poisoning in its worst forms.

Ventilation.

Ventilation is a term which has a somewhat extensive meaning. Generally it may be said to mean the removal and dispersion of foreign gases or suspended matters, which have accumulated in the atmosphere as the result of the vitiating processes already described. We speak of the ventilation of streets and buildings, the ventilation of inhabited rooms, factories, and mines, and the ventilation of drains and sewers. In each case the same object is aimed at, but the means by which it can be attained are different. The ventilation of streets and buildings is concerned with the width of the street, and the height of adjoining or opposite buildings—in fact, with the amount of free air space around the buildings, and the facilities afforded for the entrance of light and air. This may be called external ventilation. To ventilate dwelling-houses, factories, or mines, fresh air from outside must

be introduced within these more or less closed places by natural or artificial means, and adequate exit must be provided for used or vitiated air. It is the same for drains and sewers, with this addition, that the escaping air must be allowed exit at points where it is least likely to be productive of nuisance or danger. In addition to the natural forces of rain, wind, sun, and vegetation, which promote the purification of the atmosphere on the large scale, *natural ventilation* as applied to circumscribed localities may be said to depend upon (1) *diffusion of gases;* (2) *the action of the winds;* (3) *the difference in weight of masses of the air of unequal temperature.*

1. Gases diffuse inversely as the square roots of their densities; and this diffusion can take place through porous substances such as dry bricks. The process is necessarily a slow one, and inadequate to produce complete renovation of vitiated air.

2. Winds are very powerful ventilating agents. They act chiefly by *perflation, i.e.*, by setting masses of air in motion, driving them onward by an irresistible *vis a tergo*. They also have an *aspirating* effect on air which is shielded from the direct or perflating action. For when wind passes horizontally over chimneys, or tubes placed at right angles to its course, it causes a diminution of pressure within them, thus creating a current of air up the chimney at right angles to itself. The air in these tubes being partially aspirated or sucked out by the action of the wind, to restore the temporary vacuum so made, air from below rushes up to take its place, a continual current in a perpendicular direction being thus set up.

3. When air is heated it expands. The expansion is equal to $\frac{1}{491}$ of its volume for every degree Fahrenheit, or $\frac{1}{273}$ for every degree Centigrade. A volume of hot

air is consequently lighter, bulk for bulk, than the same volume of cold air. The warm air rises, and equilibrium is restored by the cold air rushing in to occupy its place. The winds themselves are caused in this manner by the unequal heating of the air over different parts of the earth's surface.

External Ventilation (Streets, Buildings, etc.).

The health of a town largely depends on the width of its streets, the general height of the buildings, and the amount of yard space at the rear of each building which separates it from its opposite neighbour. Contrast the health and vitality of the occupants of houses in wide open streets with those who live in narrow courts closed at one or both ends, the courts themselves being often surrounded by higher buildings, or built back-to-back, or with the smallest possible intervening space. In such places the air is almost always necessarily stagnant, as the passage of the wind is obstructed by the surrounding buildings. The sun's light—the most powerful of germicides—for many months in the year cannot penetrate, with the result that the ground is never thoroughly dried, and the air in contact with it remains continually damp. Impure gases and exhalations, evolved from the inhabited dwellings, are not at once swept away by the wind, and consequently accumulate in the air of the court and its surroundings. Suspended organic matters tend to subside in the still air, which, being thus both damp and impure, produces that state of low vitality and predisposition to disease which characterize the inhabitants of such places.

Zymotic diseases—especially typhus—when once introduced, spread rapidly through the vitiated air, the enfeebled constitutions of the inhabitants presenting but

slight resistance to their onset. Absence of sunlight appears to have a specially injurious effect on child life, which, like plants, becomes blanched and weakly when reared in semi-darkness. When it is added that in many of these courts and alleys the houses have no through ventilation, the windows being only in front of the house, it is not to be wondered at that the general death-rate is sometimes double, or even treble, that of the healthy parts of the town, and that the mortality amongst infants and young children is something appalling. All investigations into the effect of back-to-back houses upon the health of the inmates show an increased incidence of disease and mortality from all causes, phthisis, diseases of the respiratory organs, diarrhœa, and zymotic diseases generally; and in districts where such houses form about 50 per cent. of the total, the death-rates from the above-mentioned causes are nearly half as much again as the rates generally prevailing for the whole of England and Wales. Back-to-back houses are built in double rows with only one side exposed to the open air, except in the case of those houses at the ends of the blocks, which have two sides open to the external air. Through ventilation is impossible in such houses, and the rooms are generally dark and dirty as a consequence.

To show what is the minimum amount of external air space which should be allotted to every building in a town, we may quote from the model bye-laws of the Local Government Board, which refer to new streets and buildings.

The width of every street intended for use as a carriage-road must not be less than 36 feet; if not to be used as a carriage-road, it must be at least 24 feet wide, and open at one end. Twenty-four feet is the least width allowed

before the frontage of any new building; and the aggregate amount of yard space at the back of such a building, and belonging to it, must not be less than 150 square feet, and, whilst extending the entire width of the building, it must not in any case be less than 10 feet wide, and must be wider when the height of the building exceeds 15 feet.

It is important to note that the model bye-laws insist on the yard space at the back of a house being increased with the height of the house up to 35 feet, but not so the frontage area. The higher the buildings, of course the greater the obstruction to the passage of air and light, and the amount of space compulsorily left unoccupied, both in front and back, should have been correspondingly increased. The erection in London and some large provincial towns of huge blocks of industrial dwellings, whilst affording vastly superior accommodation to the working classes over the old insanitary tenements, has not always secured efficient external ventilation for certain of the tenements. Lofty blocks are too often built in such a way as to enclose a narrow and well-like court, in which the atmosphere is always sunless and stagnant, and from which the rooms facing on to it derive all their light and air. Cottage buildings with sufficient space in front and rear are far preferable to lofty blocks placed in rows; but as they do not house the same number of people for the space occupied, in crowded districts, where the land is of such enormous value, the rents must necessarily be higher.

The London Building Act, 1894, Part V., provides for open spaces about buildings and the height of buildings. Section 41 applies to domestic buildings erected after the commencement of the Act and abutting upon a street formed or laid out after the commencement of the Act, and requires to be provided in the rear of every such

building an open space exclusively belonging to it of an aggregate extent of not less than 150 square feet, the open space to extend throughout the entire width to a depth of at least 10 feet from the building. The height of the building is regulated as follows: An imaginary horizontal line is drawn at the level of the pavement from the roadway, and at right angles to it through the centre of the face of the building, and prolonged to intersect the boundary of the open space at the rear. An imaginary diagonal line is then drawn in the direction of the building above, and in the same vertical plane with the horizontal line, and inclined thereto at an angle of 63·5°, meeting the horizontal line where it intersects the boundary of the open space at the rear. No part of the building will then be allowed to extend above the diagonal line, except chimneys, dormers, gables, turrets, or other architectural ornaments. Exception is made in the case of new buildings abutting at the back upon a street or open space dedicated to the public.

With respect to new domestic buildings abutting upon a street formed or laid out before the commencement of the Act, the horizontal line may be drawn at a level of 16 feet above the level of the adjoining pavement, and the open space of 150 square feet may also be provided above the level of the ceiling of the ground story, or 16 feet above the level of the adjoining pavement.

Section 42 enacts that the sanction of the London County Council must be obtained to the plans of dwellings for the working classes to be erected after the commencement of the Act, which do not abut upon a street.

Section 45 prohibits the construction of habitable rooms lighted and ventilated entirely from enclosed courtyards, or from courtyards open on one side, but of which the depth, measured from the open side, exceeds twice the width, unless the width of the court measured from the window of the room to the opposite wall is equal to half the height measured from the sill of the window to the eaves or top of the parapet of the opposite wall.

Section 43 enables new domestic buildings, which are not artisans' dwellings, to be erected on the same sites as existing buildings, if abutting upon a street, and to cover the same extent of land, but no more than was occupied by the previously existing domestic building.

Section 47 enacts that a building (not being a church or chapel) shall not be erected of or be subsequently increased to a greater height than 80 feet (exclusive of two stories in the roof, and of ornamental towers, turrets, or other architectural features) without

the consent of the Council; provided that where any existing buildings forming part of a continuous block or row of buildings exceed 80 feet in height, any other building in the same block belonging to the same owner at the date of the passing of the Act may be carried to a height equal to, but not exceeding, that of the existing buildings.

Section 49 requires that no existing building (other than a church or chapel) on the side of a street formed or laid out after August 7, 1862, and of a less width than 50 feet, shall be raised, nor shall any building be erected so that the height of the building exceeds the width of the street, without the consent of the Council.

Section 69 provides for the ventilation of staircases both in artisans' dwellings and in ordinary dwelling houses, constructed after the Act.

Section 70 requires that every habitable room in a new building, except rooms wholly or partly in the roof, shall be in every part at least 8 feet 6 inches in height from floor to ceiling. Rooms wholly or partly in the roof must be at least 8 feet in height throughout not less than one-half their area. Every habitable room with an external wall, which is not in the roof, must have a window opening into the external air, or into a conservatory, with a total superficies clear of the sash-frames, free from any obstruction to the light, equal to at least one-tenth of the floor area of the room, and so constructed that at least one-half of such window can be opened, the opening to extend to at least 7 feet above the floor level.

Smoke Prevention.

In London the smoky atmosphere of the winter months is almost entirely due to the unconsumed smoke from private dwelling-houses, whilst in the Northern towns it is the manufactory smoke that pollutes the air, a fact at once evident from the very striking contrast between the air on Sundays and the dense smoke-cloud that overhangs the town on the working week days. To deal with the whole smoke question in London is to attack a problem of unexampled magnitude and difficulty; all that can be hoped for is that coal gas may in time be so far cheapened as to replace with economy the common use of coal for domestic heating and cooking purposes.

A smoke-laden atmosphere is impure; it reduces daylight, and therefore leads to an increased employment of artificial light; it renders it difficult and sometimes impossible to keep public buildings and private dwellings clean, and it doubtless promotes ill-health in some people.

In the Lancashire and Yorkshire towns the abatement of smoke is a far easier task to accomplish, and already a good deal has been done in this direction, by the adoption of smoke-preventing appliances in connection with factory furnaces. The smoke nuisance is chiefly due to the fireman allowing too long intervals between the firings. This leads to too much coal being put on at one firing, and the issue of black smoke; but a deficient air-draught —generally due to a small cramped flue in a low chimney —is sometimes a cause. The best method of smoke prevention is to secure frequent and light firing, and the admittance to the furnace of the necessary air to secure complete combustion of the carbon particles, after each fresh charge of fuel. Many devices are employed to secure these objects independently of the fireman. Of these appliances, perhaps the most commonly used are the mechanical stokers, which may conveniently be divided into two classes: (*a*) Those that throw small quantities of fuel evenly over the fire, and thus obviate the dense black smoke produced, under the ordinary conditions of stoking, when the fire-door is opened and fresh fuel is cast by a fireman on the fire. It is evident that with stokers of this class ("sprinklers") the fire-bars must be made to move by appropriate mechanical arrangements, and so keep the fire level and free from aggregations of imperfectly coked fuel at certain parts of the furnace.

The second kind of mechanical stokers (*b*) are those of the coking class. By these the fresh fuel is delivered

from a hopper to the front of the fire, where it gets coked; it is then gradually worked backwards on the fire-bars, until the clinker falls over the back of the grate into the ashpit. By these contrivances the furnace is continuously taking in the raw fuel at the front, burning this smokelessly (because the black smoke arising at the front of the furnace is "killed" by passing over the white-hot fuel at the back), and dropping the ashes over the other end of the bar. "Side-firing" is said to give good results. By this method the fuel is delivered at each side of the fire alternately, and the smoke from the side which is being fed curls towards the incandescent fire on the other side, and gets burned. These coking mechanical stokers give far better results than the sprinkling class.

As smoke arises from a furnace when the supply of air admitted is inadequate to secure complete combustion of the fuel, a great number of contrivances have been invented for supplying air either heated by passing through special pipes laid in the flues, or cold, to various parts of the furnace or main flue. Grids or circulars which can be opened and shut by hand are sometimes placed in the door to admit air to the furnace, and panels and louvres in the furnace door are now made to open and shut automatically. These can be regulated to admit the desired quantity of air. "Forced draughts" are often utilized to increase the draught in the furnace, and thus to favour combustion, and for this purpose jets of steam are generally admitted through the frame of the furnace just above the door. Again, split bridges or hollow fire-bars of various kinds are made to admit air. The "bridge" is the metal or brickwork projection at the back of the fire-bars, over which the flames and products of combustion pass on their way to the flue. There is a door underneath the split bridge, which can

be opened, when firing is taking place, to let the air pass up through the bridge to ignite the gases and further complete combustion. Split bridges may be made to work automatically, and many are in use; but if left continually open, they tend to destroy the draught in the front part of the furnace, and they soon get filled with ashes.

Amongst less effective appliances may be mentioned the use of fans to force the smoke again through the furnace, and the washing of the smoke by passing it through shafts in which sprays of water are descending.

There is a considerable advantage to the manufacturers in the use of mechanical stokers, inasmuch as they can by their means burn an inferior slack coal (cheaper fuel), and less labour is required. If split bridges only are used, great care is required on the part of the fireman, and fuel of fair quality must be used, or smoke is emitted; whilst the mechanical stokers do away with these sources of expense.

In conclusion, it may be said that the quality of the coal used has an important bearing on the subject of smoke prevention, and that coke and anthracite are practically smokeless. The ordinary or bituminous coal is much cheaper, weight for weight, than anthracite, but on account of the greater heat obtained from the latter it is said to be almost as cheap in use. Coal-dust firing is held by a recent Prussian Commission to possess the following advantages: It allows of uniform distribution; it permits of perfect combustion without smoke; and secures the greatest calorific efficiency.

Section 91 of the Public Health Act defines as a nuisance "any fireplace or furnace which does not as far as practicable consume the smoke arising from the combustible used therein, and which is used in any manufacturing process whatsoever." The same section

provides that the court to which an appeal may be taken shall dismiss the complaint if it is satisfied that such furnace is constructed in such a manner as to consume as far as practicable its smoke. It should be noted that, according to Section 91 of the Public Health Act, 1875, when any chimney (not being the chimney of a private dwelling-house) is sending forth *black smoke* in such quantity as to be a nuisance, it is not necessary to prove, in order to secure a conviction, that the furnace is improperly constructed or inefficiently tended. A conviction must follow the proof of the emission of "black smoke in such quantity as to be a nuisance."

The London County Council is of opinion that the escape of black smoke for five minutes from the lighting of the furnace might be permitted, but that afterwards a discharge of one minute or more should be the subject of legal procedure. The allowance varies from two to fifteen minutes in other large towns.

Ventilation of Inhabited Rooms.

In providing for the ventilation of inhabited rooms by the replacement of vitiated air by fresh air, it has been found necessary to adopt a certain standard of impurity above which no increase should be allowed; because it is impossible in a cold climate to provide the enormous volumes of fresh air (about 1,000,000 cubic feet for each individual per hour) which would be necessary to keep the air of the room as pure as the outside air. It is only out of doors, then, that we can be constantly breathing air of normal purity, as indicated by its amount of CO_2 (0·04 per cent.).

It was found by the late Professor de Chaumont, by chemical examination of a large number of samples of

the air of inhabited rooms, that—the amount of CO_2 in the outer air being 0·04 per cent., or 0·4 per 1,000—no close or disagreeable smell is perceived in the air of a room until the CO_2 from human respiration reaches 0·6 per 1,000, or exceeds by 0·2 per 1,000 that present in outer air, the close smell being always due to the foul organic matter in the impure air, which increases *pari passu* with, and is therefore estimated by, the amount of CO_2 present. When the CO_2 in an inhabited room reaches 1·3 per 1,000, the limit of differentiation by the sense of smell, when a person first enters such a room from the outer air, is reached. Any greater impurity than this cannot be distinguished by the unaided senses. It was assumed by De Chaumont, and experience has confirmed his assumption, that air vitiated to the extent of 0·2 per 1,000—air which is still fresh and does not differ sensibly to smell from the outer atmosphere—can be breathed with impunity, but that no greater vitiation ought to be allowed. The object of ventilation may be said to be the supply of sufficient pure air to a room to prevent the CO_2 rising above 0·6 per 1,000. The permissible limit of respiratory impurity is therefore 0·2 per 1,000 (0·2 part of CO_2 per 1,000, or 0·2 cubic foot of CO_2 per 1,000 cubic feet of air; which is the same thing as 0·0002 cubic foot of CO_2 per 1 cubic foot of air).

If an adult were enclosed in an air-tight chamber 10 feet high, 10 feet wide, and 10 feet long—*i.e.*, in a chamber containing 1,000 cubic feet of space—in an hour the CO_2 in this chamber would have had added to it 0·6 cubic foot of CO_2; the air originally contained 0·4 part of CO_2 in 1,000 parts, so that after one hour it would contain $0·4 + 0·6 = 1$ part of CO_2 per 1,000, or $1 - 0·6 = 0·4$ per 1,000 above the permissible limit of impurity. But if the subject of this experiment were

enclosed in a chamber containing 3,000 cubic feet of space, in one hour the amount of CO_2 would be only $\frac{3 \times 0{\cdot}4 + 0{\cdot}6}{3} = 0{\cdot}6$ per 1,000—*i.e.*, the limit would just have been reached; and at the end of a second hour, to keep the CO_2 down to this limit, 3,000 cubic feet of fresh air from outside must have been allowed to enter the room. We thus see that an adult individual, when at rest, should be supplied with 3,000 cubic feet of fresh air per hour. In a similar way it can be shown that when the adult male is doing gentle work (and giving off 0·9 cubic foot of CO_2 in the hour) he theoretically requires 4,500 cubic feet of fresh air per hour; and if he is engaged in very hard work (and giving off, maybe, 1·8 cubic foot of CO_2 per hour) he needs as much as 9,000.

By the equation $D = \frac{E}{r}$—where E = amount of CO_2 exhaled, r = respiratory impurity per cubic foot of air, and D = the delivery, or the amount of fresh air available in cubic feet—if E and r are known we can find D, or if D and E are known we can find r. If E = 0·6, and $r = 0{\cdot}0002$, then $D = \frac{0{\cdot}6}{0{\cdot}0002} = 3{,}000$. That is to say, an adult requires 3,000 cubic feet of fresh air per hour in order that the respiratory impurity may not exceed 0·2 per 1,000, or—what is the same thing—the total impurity 0·6 per 1,000.

*Example.**—If a room of 1,000 cubic feet is occupied for four hours by 10 persons, each giving off an average amount of CO_2, what will be the total amount of CO_2 per 1,000 volumes at the end of the time, supposing 10,000 cubic feet of fresh air per hour have been supplied?

In this problem D and E are given, and we have to find r. The

* Sanitary Science Examination, Cambridge, 1880.

total amount of air available for breathing by the 10 persons in the four hours is 1,000 cubic feet (the cubic space of the room) + 10,000 × 4 cubic feet (the amount supplied in four hours) = 41,000 cubic feet = D. The amount of CO_2 expired by 10 persons in 4 hours = 0·6 × 10 × 4 = 24 cubic feet = E.

$$D = \frac{E}{r} \text{ or } r = \frac{E}{D} = \frac{24}{41,000} = 0·00058;$$

i.e., *r*, or the respiratory impurity, is 0·58 part per 1,000. The total amount of CO_2 in the air will be 0·58 + 0·4 = 0·98 part per 1,000.

Example.†—The air of a room occupied by 6 persons, and containing 5,000 cubic feet of space, yields 7·5 parts of CO_2 per 10,000 parts. How much air is being supplied per person per hour?

Here E and *r* are given, and we have to find D. E = 0·6 × 6 = 3·6 cubic feet CO_2 exhaled in one hour. $r = 7·5 - 4 = 3·5$ per 10,000, or 0·35 per 1,000, or 0·00035 part of CO_2 per cubic foot.

$$D = \frac{3·6}{0·00035} = 10,285.$$

But the room contains 5,000 cubic feet of space; therefore in the first hour 5,285 cubic feet of fresh air were supplied, or 880 cubic feet per head. After the first hour, to maintain the same amount of CO_2 in the air, the full 10,285 cubic feet of fresh air will have to be supplied, or 1,714 cubic feet of fresh air per head per hour.

During exertion a man gives off more respiratory impurities (CO_2, organic matters, etc.) than when at rest. For this reason, and also because the air is generally further vitiated by the trade process, the amount of air supplied to factories or workrooms should be considerably in excess—double, or even treble, according to the nature of the work—of that required in an ordinary living or sleeping apartment. Some allowance, too, must be made for lights, especially gaslights, when the products of combustion are allowed to escape into the air of the room. An ordinary small gas-burner, under a pressure equal to 1 inch of water, consumes about 3 cubic feet of gas in an hour, producing about $1\frac{1}{2}$ cubic feet of CO_2, besides traces of sulphurous acid and other

† Sanitary Science Examination, Cambridge, 1884.

injurious gases, and much heat and watery vapour. It is true that no foul organic matters are given off in gas combustion ; but, still, it is necessary to dilute and carry away these products of combustion, which take the place of the oxygen in atmospheric air, and are in themselves more or less injurious to health.

The amount of *cubic space* allotted to each person in a room is a matter of great importance, not because cubic space, however large in amount (as met with under ordinary conditions of inhabited dwellings), can take the place of a regular supply of fresh air from outside, but because the larger the cubic space, the easier it is to supply the proper amount of air without creating a draught. For instance, suppose in a dormitory occupied by ten persons the amount of space per head is only 300 cubic feet, to supply 3,000 cubic feet of fresh air per head per hour 30,000 cubic feet must be admitted in this period, and the air of the room will be completely changed ten times—a proceeding which would cause in cold weather, unless the entering air was warmed, a most disagreeable draught. But if the cubic space per head be 1,000 cubic feet, then the air of the dormitory need be changed only three times per hour ; and if such renewal is effected steadily and gradually, the cold entering air is broken up, and, mixing with the warmer air of the apartment, creates no draught.

A certain amount of *superficial* or *floor space* is necessary for each individual, for if the height of the room is much over 12 feet, excess in this direction does not compensate for deficiency in the other dimensions, although the total cubic space may be the same ; thus, it would not be the same thing to allow a man 50 square feet of floor space in a room 20 feet high as to provide 100 square feet in a room 10 feet high, although the cubic space would be

identical. The reason is that the organic matters of respiration are not equally diffused throughout the air of an apartment, but tend to accumulate in the lower strata, consequently excessive height does not, in their case, mean a corresponding dilution.

A few examples of the cubic and superficial space allotted under various circumstances may be interesting:

	Minimum Space per Head in Cubic Feet.	Authority.
Common lodging-houses (sleeping rooms)	300	Local Government Board.
Registered lodging-houses— Rooms occupied by day and night	400	Local Government Board.
Rooms occupied by night only	300	Local Government Board.
Non-textile workrooms ..	250	Factory Act, 1895.
Non-textile workrooms during overtime	400	Factory Act, 1895.
Army barracks	600	British Army Regulations.
Army hospital wards	1,200	,, ,, ,,
Public elementary schools ..	100*	Education Department.
London Board Schools ..	130†	London School Board.
Canal boats (persons over twelve years)	60‡	Local Government Board Regulations under the Canal Boats Act, 1877.
Canal boats (persons under twelve years)	40‡	Local Government Board Regulations under the Canal Boats Act, 1877.
Seamen's cabins	72	Merchant Shipping Act.
Cows in cowsheds	800	Local Government Board Model Regulations under the Dairies, Cowsheds, and Milkshops Order.

Natural Ventilation.—During the colder months of the year in this country a complete change of the air in an inhabited room, not greater than three times in an hour, is all that can be borne when the entering air is not artificially warmed. Hence the importance of an allow-

* Minimum floor space 8 square feet.

† Minimum floor space 10 square feet.

‡ An after-cabin must not be less than 180 cubic feet in capacity, nor a fore-cabin less than 80.

ance of cubic space not much less than 1,000 cubic feet for each individual. The area of the inlet opening should be sufficiently large to allow the required volume of air (3,000 cubic feet) to enter at no greater speed than 5 feet per second, or about 3·4 miles per hour. This speed could be attained where the inlet opening for each individual was 24 square inches. During cold weather this velocity could not be borne; and it may be said generally that efficient ventilation cannot be tolerated by anyone in cold weather, unless the entering air is artificially warmed. A velocity of the entering air of 2 to 3 feet per second is far more agreeable to the senses than a velocity of 5 feet; and if the air is artificially warmed to 60° F., the area of the inlet opening may be enlarged to 48 square inches for each individual, and the warmed air may then be supplied at a rate of $2\frac{1}{2}$ feet per second. This would be by far the most agreeable form of ventilation in cold weather. If the entering air is artificially warmed, the size of the inlet opening may even be increased up to 70 or 80 square inches per head, and the amount of cubic space may be diminished, for it would be possible then to change the air of the apartment more frequently than three times per hour without creating a draught.

Of the forces which act in natural ventilation, diffusion causes the gaseous impurities of respired air to mix with the fresh air in a room until homogeneity is established. Diffusion, however, does not affect the suspended matters, which tend to fall towards the earth in a still atmosphere.

The perflating action of the wind may be utilized by opening windows facing the wind, and the action is increased when windows, or a window and door on opposite sides of a room, are left open. The room is

rapidly and continually flushed with air, an enormous effect being produced, for it is possible to renew the air of a room in this manner over a hundred times an hour, even when the movement of the wind outside is only 2 miles an hour, or 3 feet per second, equivalent to a very gentle breeze. Such a method is of unquestionable utility for rapidly changing the air of an unoccupied room—especially school and work rooms—and may be generally put in operation in inhabited rooms in summer when the temperatures outside and inside the house approximate.

In any system of ventilation, however, that depends entirely on the wind, there is always the difficulty of regulating the velocity of the current, and during complete calms the action is of course nil. The wind, too, often impedes ventilation by obstructing the passage of vitiated air from an exit shaft into whose mouth it blows; and this is not to be wondered at, for when blowing at the rate of 10 miles an hour the pressure of the wind is $\frac{1}{2}$ pound on each square foot of surface.

For ventilating the holds and cabins of ships at sea, the wind may be most advantageously utilized. A large cowl, placed so as to face to the wind, conducts the air below by means of a pipe, whilst another cowl, reversed so as to back to the wind, allows the used air to escape. By this exit shaft the aspirating force of the wind is utilized. Sylvester's system of house ventilation proceeds on the same principles. A large cowl facing the wind is placed outside the house, and conducts the air to an underground chamber, where it can be warmed if necessary by passing over hot-water or steam pipes; it is then conducted to the rooms above by means of tubes, and finally escapes above the roof through tubes surmounted by cowls backed to the wind.

The aspirating action of the wind is constantly being used to ventilate rooms by means of the chimney. With a fire burning in the grate, the draught up the chimney is increased by the aspiration of the wind when the top of the chimney is above surrounding buildings. Even when there is no fire in the grate, it will usually be found that there is a current setting up the chimney. Should the top of the chimney be lower than surrounding structures, the wind striking these and then descending will often cause a back-draught and a smoky chimney. The remedy is evidently to carry up the chimney to at least the height of the surrounding buildings. A lobster-back revolving cowl surmounting the chimney may prevent or mitigate back-draught; but it should be clearly understood that no sort of cowl that was ever invented can increase the up-draught in a chimney, no matter whether the top is overlooked or not by higher buildings in its neighbourhood. Another cause of smoky chimneys is an insufficient supply of air to the room. To feed the fire, air is drawn down the chimney, and coming down in puffs, it causes an escape of smoke. The remedy is obtained by making a suitable inlet for fresh air into the apartment.

The movement produced by inequality in density or weight of contiguous masses of air at different temperatures is the natural force chiefly relied on for ventilating the interior of houses in this climate. This force is naturally chiefly called into action in cold weather, when the difference between the internal and external temperature is considerable, and is more or less in abeyance in summer, when the temperature outside is often equal to, or even higher than, that of the house. The greater this difference of temperature and the difference of level between the aperture for the entrance of cold air and the

aperture for the exit of heated air, the greater will be the velocity of the entering air. We are enabled to calculate the theoretical velocity by means of Montgolfier's formula, which is founded on the dynamical law that the velocity in feet per second of falling bodies is equal to eight times the square root of the height through which they have fallen. In this case the height fallen is represented by the difference in pressure of the air inside and outside the house, which is equal to the difference of level between the apertures of entrance and exit multiplied by the expansion of air caused by the difference in temperature inside and outside.

$v = 8\sqrt{\frac{(h-h')\,(t-t')}{491}}$ = velocity in feet per second,

where h = height of aperture of exit from ground;
,, h' = ,, ,, of entrance from ground;
,, t = temperature of air inside in degrees Fahr.;
,, t' = ,, ,, outside in degrees Fahr.

In practice an allowance for friction of $\frac{1}{4}$ or $\frac{1}{2}$ must often be made. As it is impossible to tell, with any degree of accuracy, what allowance must be made for friction in any given instance, the formula is little employed in actual practice, and the anemometer is preferred. If the area of the inlet opening is known, the amount of air entering the room in a minute or hour can easily be calculated by multiplying the velocity by the area of the inlet expressed as square feet, or as a fraction of a square foot.

In a room as usually constructed with sash-windows and with a fireplace and chimney, but without any special means of ventilation, when a fire is burning in the grate, the fresh air entering the room gets warmed as it approaches the fire, and part ascends the chimney flue while part rises to the ceiling. Cold air from outside will

then enter—if the windows are closed—under the door, under the skirting boards, between the sashes of the window, and through any other chinks or apertures due to loose fittings. The bricks and plaster of the walls are also porous to a certain extent, and if uncovered by paint or wall-paper will admit a small quantity of air. Thus a large volume of air may be entering a room in cold weather when the fire is burning, although there are no visible inlets; and the amount of air thus supplied may be sufficient for the needs of two or three persons if it were properly distributed. But such is not the case. The cold air, which enters chiefly near the floor, takes as straight a course as possible to the fireplace, producing a disagreeable draught to the feet of the occupants, whilst the heated and vitiated air near the ceiling is left undisturbed.

It has been found practically that, in this country, to prevent draughts and to insure a thorough distribution, fresh air not previously warmed should be admitted into the room above the heads of the occupants, an upward direction being given to it so that it may rise towards the ceiling, mix with and be warmed by the heated air in this situation, fall gently into all parts of the room, and be gradually removed by means of the chimney flue, or other outlet—which should preferably be at the highest part of the room.

Amongst simple contrivances for windows by which these objects may be attained may be mentioned Hinckes-Bird's method (Fig. 26), now so well known, of placing a solid block of wood under the entire length of the lower sash frame of a window, so as to raise the top of the lower sash above the bottom rail of the upper sash. By this means the air is admitted between the two sashes above the heads of the occupants of the room,

and is given an upward direction towards the ceiling. Holes bored in a perpendicular direction in the bottom rail of the upper sash, louvred panes (Fig. 28) to replace one of the squares of glass, an arrangement for allowing

FIG. 26.—HINCKES-BIRD'S WINDOW VENTILATOR.

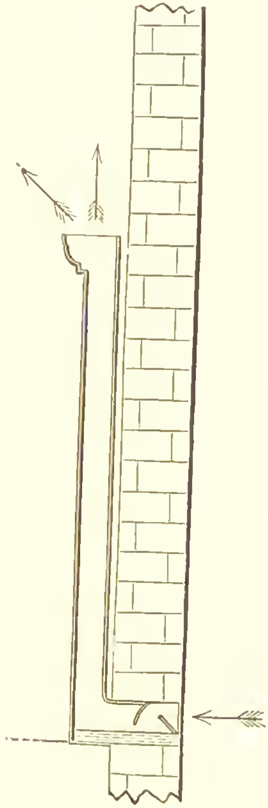


FIG. 27.—TOBIN'S TUBE WITH WATER-TRAY.

one of the squares of glass, provided with side-checks, to fall inwards upon its lower border, or a double pane of glass in one square, open at the bottom outside and at the top inside, all effect the same purpose and are simple and inexpensive contrivances. Cooper's venti-

lator (Fig. 28), which consists of a series of apertures in the glass of a window-pane, arranged in a circle and capable of being more or less completely closed by a circular glass disc, also with apertures, and movable on a central pivot, does not admit the air in an upward direction, but breaks it up into a number of divided currents, thus lessening the tendency to draught. The same object can be obtained by placing wire gauze or

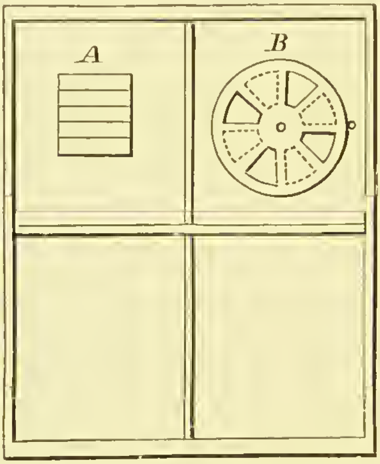


FIG. 28.—WINDOW VENTILATORS.
A, Louvre. *B*, Cooper's.

muslin over any inlet opening. The most generally used wall inlet ventilators are Sheringham's valve, Tobin's tube, and Ellison's conical bricks.

In the Sheringham valve (Fig. 29) air passes through the wall by means of a perforated iron plate, and is then directed upwards by a valved plate with side-checks, which projects into the room, and, being hinged at its lower border, is capable of being more or less completely closed by a balance weight. The usual size of the inlet opening in these ventilators is 9 inches by 3, giving an area of 27 square inches.

In Tobin's tube (Fig. 27) air is introduced from the outside at the floor-level through a perforated plate, and then passes up a vertical tube to a height of from 4 to 6 feet above the floor. After escaping from the tube, the current of air ascends more or less vertically for several feet, before it begins to spread out and mix with the air of the room. In these two contrivances (Tobin's tube and the Sheringham valve) the entering air may be filtered through muslin or cotton wool, or made to impinge upon a tray containing water, and so deposit its sooty particles — a procedure often advisable in smoky towns.

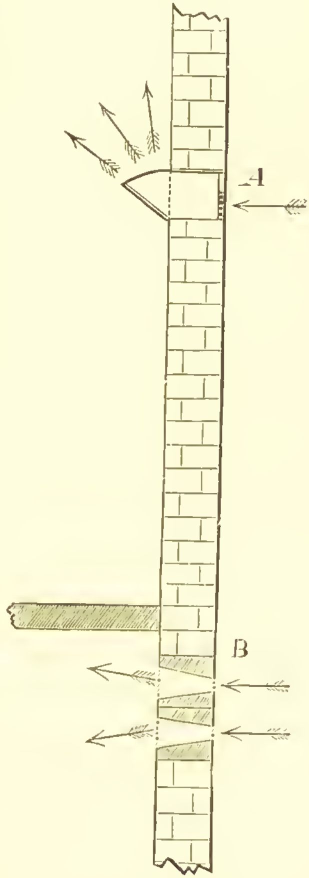


FIG. 29.—*A*, SHERINGHAM'S VALVE. *B*, ELLISON'S CONICAL BRICK VENTILATORS.

Tobin's tubes and other inlet and outlet ventilators should be made accessible in all their parts for cleansing, as they quickly become lined internally with dirt and adherent filth. Tobin's tubes should be made detachable from the external wall opening for this purpose.

Ellison's bricks (Fig. 29) are pierced with conical holes, the small opening, $\frac{1}{5}$ inch in diameter, being placed outside the house, whilst the larger opening, $1\frac{1}{4}$ inches in diameter, is placed inside. The thickness of the brick is $4\frac{1}{2}$ inches. The air passing through these conical apertures becomes distributed over a gradually

increasing area, and in this way its entrance is rendered imperceptible and unproductive of draught.

All the inlet ventilators now described are intended to utilize the movements produced by contiguous masses of air at unequal temperatures. For this reason they should be protected as far as possible from the perflating action of the wind. This cannot, however, always be done; and when a strong cold wind is blowing into a ventilator, even of the most approved sort, a most unbearable draught is the result. To obviate this, there should be some means of controlling the amount of entering air by partially closing the ventilator, and in many cases the ventilator must be closed altogether. Sheringham's valve, Tobin's tube, and louvred inlets, fulfil these requirements very satisfactorily. It is often found that inlet ventilators are acting as outlets for the escape of air, when fresh air is entering a room from other sources. This cannot be obviated, nor, indeed, is it necessary. All that can be done is to place the inlets in the best possible position for distributing the entering air throughout the apartment without causing a draught, and to close up all such sources of entering air as are productive of draughts.

The usual outlet for the vitiated air of a room is the chimney flue; and this, for an ordinary medium-sized sitting-room, with a fire burning in the grate, is sufficient for three or four people, provided no gas is alight, or the gas-lamp has its own special ventilating arrangement. With an ordinary fire, from 10,000 to 15,000 cubic feet of air are drawn up the chimney in an hour, the current being generally from 3 to 6 feet per second; but a large fire will often induce a current of 8 or 9 feet per second.

Heated air rises to the top of a room; therefore the

proper place to admit of the vitiated air escaping is in or near the ceiling.

Neil Arnott's or Boyle's valves (small talc plates), which open into the chimney flue near the ceiling, are sometimes used as outlets for foul air. They permit air to pass into the flue, but prevent its return; the objections to their use are that they occasionally permit the reflux of smoke into the room, and the movements of the plates produce a slight clicking noise. If exit shafts other than the chimney flue are provided, they should be short and straight, and capable of being readily cleansed; otherwise friction, and loss of heat by passage of the air through an exposed tube, will stop the current altogether, or reverse it, causing a back-draught. The escaping air must have its temperature kept up, or it may become cooler than the air of the apartment.

One of the best methods of attaining this object, which might be put in practice in all new buildings, is to construct a shaft at one side of or surrounding the chimney flue, with an inlet near the ceiling of the room, and the outlet at the level of the chimney top. The air escaping from the room will then have its temperature kept up by contact with the chimney flue, thus aiding the up-draught, whilst the risk of reflux of smoke will be avoided. The air flues may be moulded in the same piece of fire-clay as the smoke flue; but those from different rooms should not be connected in any way, or foul air from one room might pass into another.

The combustion of gas may be made a very effective means of getting rid of foul air. It has been found by experiment that the combustion of 1 cubic foot of coal-gas causes the discharge of 1,000 cubic feet of air. An extraction shaft may be placed over a gas-lamp or chandelier; or by means of a Benham's ventilating

globe-light, or a Mackinnel's ventilator, slightly warmed fresh air may be admitted at the same time as foul air is extracted.

Mackinnel's ventilator is very useful for a room which has no other apartment over it. Two tubes, one inside the other, are carried through the ceiling or roof of the building. The inner one, which is for the extraction of foul heated air, projects outside above the outer, and inside also below it. At its lower end a broad circular horizontal rim is attached to the inner tube which deflects the air entering by the outer tube, and causes it to pass for a short distance parallel to the ceiling before falling into the room, as otherwise the fresh air would be drawn round into the inner or exit shaft. The gas-burners or lamps used to light the room may be placed immediately under the inner tube of this ventilator. The inner or extraction tube should have its top protected by a cover or cowl, to prevent the wind blowing down and the entrance of rain, which by evaporation might so cool the escaping air as to cause it to be heavier than the air of the apartment. The entering air will be slightly warmed by its passage over the heated extraction shaft. The area of the outer tube for the passage of fresh air should be equal to, or slightly larger (for there is more friction to overcome) than, the area of the inner tube for exit of foul air. Mackinnel's ventilator is well adapted for large buildings, as schools, churches, halls, etc., which have no upper floors or stories. Benham's ventilating globe-light, as its name expresses, combines ventilation and lighting; slightly warmed fresh air is admitted, and foul air is extracted along with the products of combustion. In theatres sunlight burners are largely used; they aid the extraction of foul air, but do not admit fresh air.

In Pott's method of ventilation a hollow metallic perforated cornice is divided into an upper and lower half by means of a horizontal plate. Pure air enters the room through the lower half, which communicates with the outside air, and foul air is extracted through the upper half, which opens into the chimney.

Extraction shafts, like inlet openings, are liable to have their action reversed under certain circumstances. When the wind is blowing down upon them, when rain gets in, when the escaping air is subject to much cooling in an exposed shaft, or when there are more outlets than one in a room, one predominating over the others, down-draughts are likely to occur. This most frequently happens when the draught up the chimney is very great from there being a large fire burning; then there is a tendency for every other opening into a room to become an inlet. Also, when the wind is blowing down an exit shaft or chimney flue, the windows or inlet ventilators may become outlets. These matters can, however, generally be regulated by attention to the facts and principles which have been already laid down as a guide to proper ventilation.

It will be convenient to mention in this place some facts with regard to loss of velocity in air shafts by friction. The actual loss can in some cases be determined by calculating the theoretical velocity in an air shaft by Montgolfier's formula, and then ascertaining practically by means of a current meter or anemometer the actual rate at which the air is issuing or escaping. The difference represents the loss due to friction; but allowance must of course be made for disturbing forces such as the perflating or aspirating action of the wind. Contrasting two similar tubes of equal sectional area, the loss by friction will be directly as the length of the

tube. If the two similar tubes are of unequal size, the loss by friction is inversely as the diameter of the cross-section in each.

When two tubes are dissimilar in shape, the loss by friction is inversely as the square roots of the sectional areas. A circle is a figure which includes the greatest area within the smallest periphery; thus, if there are two tubes, one of which is circular in section and the other square, but having the same area (1 square foot), the loss by friction is directly as the periphery, and in this case is as $\frac{3\frac{1}{2}}{4}$, the periphery of the square being 4 feet and of the circle $3\frac{1}{2}$ feet. Every right angle in a bent shaft diminishes the velocity of the current one-half. It will thus be seen that air-shafts should preferably be circular in section, short, and straight, so as to diminish the loss by friction as far as possible. The absurdity of ventilating soil pipes and drains by narrow pipes, 1 inch or less in diameter, of great length, and bent on themselves often to a right angle, is apparent from the above statements. The ventilation of drains is always difficult to establish; carried out by such methods it becomes an impossibility.

Ventilating appliances whose object is the supply of artificially warmed air will be considered separately in the chapter on heating and warming.

Artificial Ventilation.—Under this heading are usually described methods of extraction of air from inhabited buildings by means of heat, steam, or fans; and methods of propulsion of air into buildings by mechanical means. It has been found convenient to describe under natural ventilation of rooms the ventilating effects produced by fires and chimneys in ordinary rooms; and the extractive properties of gas lights have been also alluded

to, although, properly speaking, fires and gas are artificial means of ventilation.

The fire and chimney of an ordinary sitting-room are types of the methods used on a larger scale for extraction by heat. The principle is the same in all, and depends on the heating of a column of air in an extraction shaft, which being thus made lighter ascends; as long as the heat is applied, a continual current of air towards the shaft is produced, which, in its turn being heated, ascends and escapes, to be replaced by more from below.

It is in this way that some mines are ventilated. The underground workings and galleries of the mine are connected with two large shafts, usually from 8 to 12 feet in diameter, leading to the open air—an upcast shaft and a downcast shaft—in such a manner that, if air is made to pass down the downcast or intake shaft, it has to travel through all the workings of the mine before it can escape by the upcast or return shaft.

The power which produces this continued movement of air is supplied by a furnace at the bottom of the upcast shaft exerting an extractive force by the heated column of air, as previously described. In many mines the extractive force is exerted by means of a powerful rotary exhaust fan placed at the top of the upcast shaft; such fans can be made to propel some 12,000 cubic feet of air per minute. Numerous doors and partitions are necessary in the galleries and workings in order to make the air traverse the whole length of these, and prevent its taking short-cuts. An enormous volume of fresh air must be passed through a mine in the course of every hour in order to supply the quantity necessary for the respiration of the men and ponies employed underground, and to withdraw the products of combustion of lights

(lamps and candles) and agents used for blasting, and replace these injurious gases by pure air.

Where fire-damp (CH_4) is evolved from the strata cut through, the ventilation must be even in excess of these requirements, in order to dilute this gas sufficiently to prevent its forming an explosive compound with atmospheric oxygen. The same may be said with regard to the evolution of carbonic acid from the rocks underground, which so frequently takes place. This gas must not be allowed to form much over 1 per cent. of the underground air, or its asphyxiating properties will be exerted on all animal life within its influence. The injurious effects produced by gunpowder blasting, which have been already mentioned (p. 228), as the result of the evolution of so many poisonous gases into the air, are no longer necessary evils in the life of the collier or coal-miner since the introduction of cartridges made of quick-lime, which swell up from slaking when water is run over them, and exert their action without producing any gas at all. By the use of such cartridges there is, besides, no risk of explosion from ignition of fire-damp, or of coal dust. Other substitutes for explosives in fire-damp collieries are plugs of dry wood, which swell when wetted, wedges worked by hydraulic pressure, and cartridges containing compressed air at extremely high pressures.

Dynamite is now largely used instead of gunpowder, as it is more powerful, may be used under water, and requires no hard tamping. It is a mixture of nitro-glycerine $C_3H_53(NO_3)$ and infusorial earth or kieselguhr. Carbonic oxide is not one of the products of its explosion under pressure; and hence its superiority to gunpowder, in which carbonic oxide forms $7\frac{1}{2}$ per cent. of the explosive gases. There is besides no formation of sulphuretted hydrogen and marsh gas when dynamite is

exploded. These gases form respectively about 2 per cent. of the total gases resulting from gunpowder explosion. Carbonic acid and nitrogen form nearly the entire bulk of the gases resulting from nitro-glycerine explosion in closed vessels. Nitrated gun-cotton and blasting gelatine (nitro-cotton and nitro-glycerine) are also superior to gunpowder for the same reasons, carbonic acid and nitrogen forming almost the entire bulk of the gases generated when these substances are exploded under pressure.*

The new explosive termed roburite has been lately introduced into some Lancashire collieries. It is a mixture of nitro-benzenes and ammonium nitrate, and exerts its explosive powers without the production of any flame such as might ignite coal dust or inflammable gas in the mine. Several cases of poisoning, however, have occurred amongst the miners, both from handling the cartridges and from breathing the fumes after explosion. It appears that the nitro-benzol is capable, when handled, of being absorbed into the system through the skin. In the blood it is reduced, forming aniline, which gives rise to cyanosis, dyspnœa, and syncope. The poisoning from the fumes after explosion is probably due to the generation of a certain amount of carbonic oxide. From the report of a committee appointed to inquire into the effect of roburite on the health of the workmen, it appears that if stringent regulations are enforced to prevent handling of the cartridges, and to insure thorough ventilation of the workings after explosion, before the miners approach, no harmful conditions need arise.

Notwithstanding the importance of an abundant supply

* "Encyclopædia Britannica," article on "Mining," by C. Le Neve Foster, D.Sc., F.R.S.

of pure air to all the workings of a mine, it has been found impossible by the Government inspectors to insist even on so low a standard of purity as that indicated by 0·25 per cent. of CO_2 in the air. It is said that in every mine at least 6,000 cubic feet of fresh air per hour should be supplied for every man employed below, for if this quantity is much reduced there is a serious diminution in the amount of work performed by the men, so that even commercially it pays employers to have adequate ventilation. In mines where fire-damp or choke-damp is evolved, the amount of fresh air supplied should exceed this figure. The furnace at the bottom of the upcast shaft must be regulated according to the number of men employed and the amount of work that is going on at any time below-ground.

Public halls, hospitals, and other large buildings are sometimes ventilated on the extraction principle. Shafts for the escape of vitiated air lead from the different rooms and open into the chimney just over the furnace. The air from these shafts should not be used to supply the fire or furnace, but should open into the flue just above it, where the draught is greatest.

The column of air in the extraction shaft may be heated by steam or hot-water pipes instead of by a fire. This is the plan adopted at the Hôpital Lariboisière in Paris. The extraction shaft is heated throughout the greater part of its length by spiral hot-water pipes coming from a boiler in the basement. These hot-water pipes are also carried into the wards, where they are coiled so as to warm the fresh air entering from without; they then return to the boiler, and thus complete the circuit. The tubes from the wards for the escape of foul air open into the bottom of the extraction shaft. In summer the circulation of hot water in the

pipes in the wards is stopped, the circuit being completed by return pipes from the top of the extraction shaft, so that the ventilation continues, but the air entering the wards is not artificially warmed.

The column of air in the extraction shaft may be heated by gas instead of by fire; but this method is more suitable for the smaller tubes used as exit shafts in ordinary sized dwelling-rooms. Foul air may also be extracted by passing a steam jet into a chimney or upcast shaft. The shafts for the escape of foul air must open into the extraction shaft below the steam jet. The cone of steam emitted from a boiler is said to set in motion and drive before it a body of air equal to 217 times its own bulk.

On board steamships and men-of-war it has been found that very effective ventilation can be obtained by causing the furnaces to extract the air from all parts of the ship through special shafts. By this means also, if the boilers and steam apparatus are enclosed in iron casings, as far as possible, within which the air shafts open, the temperature of the stokehole is greatly reduced.

Some of the chief objections to the method of extraction by heat are: (1) Where the heat is produced by a furnace, it is most difficult to keep this at a constant temperature, consequently the draught is often very irregular. This difficulty is not encountered where the extraction shaft is heated by steam, gas, or hot-water pipes, or where the air in it is forced upwards by steam. (2) In all cases where a number of air conduits from rooms at different distances open into an extraction shaft, there is a great tendency to create powerful currents from rooms that are near, and have short conduits leading from them; whilst from the distant

apartments with long and perhaps much-curved conduits the current may be very slight, or even nil. This difficulty may to a certain extent be overcome by increasing the diameter of the longer pipes so as to reduce the friction, and by bending the shorter pipes so as to increase it; but in practice it is a rather serious drawback. (3) When air is drawn out of a room it is somewhat difficult to control the entrance of fresh air to supply its place, especially with regard to its points of entry, and its exclusion from places such as water-closets, from which it is most desirable that no air should be taken.

In the ventilation of factories, steam may often be economically and usefully applied as the extraction force, but extraction by fans has also been largely used, and presents considerable advantages, as the amount of draught can be nicely regulated by altering the speed (the number of revolutions per minute) at which the fan is driven. It is especially in the textile trades—in the cotton, woollen, silk, worsted, and flax factories—that ventilation is most urgently needed. In many of the processes of these manufactures the work is not only carried on in clouds of dust, but also in greatly heated atmospheres which are saturated with moisture, this being necessary in some instances to the proper performance of the work. To carry off the floating particles of dust, it is necessary to induce a powerful current in the exit shaft, so that the air may be drawn in as if to a vortex. In some cases the opening into the exit shaft may be in the centre of the room; but it is more often advisable to carry the dust away as soon as it originates, and before it can mix with the general air of the apartment.

Thus, in the wool-sorting trade, each bench on which

the wool is sorted has an opening leading by means of a pipe into the extraction shaft, at the extremity of which the exhaust fan is working. When the wool is being shaken, the dust, amongst which may be the spores of *Bacillus anthracis*, is drawn into the tube, and does not mix with the air which is inhaled by the workmen. The dust is then driven into settling chambers, where it is damped by steam jets, and so deposited can be collected and burnt. In silk-dressing processes, air tubes are placed above the machinery with dependent hooded openings, which cover the area of dust production and quickly remove the dust; such flues either lead into the chimney flue, or have a powerful draught created in them by means of fans placed towards the end of the shaft which leads from them to the outside air. In the dry grinding processes of the metal trades, the air tubes are placed level with the grindstones and have openings opposite each stone, in such positions as to catch the dust, as it is driven off, and carry it away at once. The best material for the exit shafts and tubes is galvanized sheet iron, as it can be made into smooth circular pipes. Arrangements must be made to provide that the draught from the benches, or the workrooms nearest the fan, is not so great as to prevent the shafts at a distance from working properly.

A very convenient form of fan is that known as the Blackman Air Propeller; it can be used for exhaustion or for propulsion, and is very powerful in its action, its vanes being large and curved. Another good form of fan is that known as the Sturtevant "blower." They can be driven by a gas or steam engine, by water or electricity, and are employed for removing dust, foul air, or fumes and steam. When used for propelling air into a building, the rate of movement in the main conduit

should not exceed 5 feet per second, and, where delivered into the rooms, not more than $1\frac{1}{2}$ or 2 feet per second. The sectional area of the air shafts should be at least equal to that of the fan, so as to reduce resistance by friction. The warmed fresh air should be delivered by the pipes into the rooms near the ceilings. As it cools, it descends, and becomes equally distributed over every part. No special exit shafts are required, and those existing near the ceiling should be closed. The air finds its way out through fireplaces, doors, windows, or the innumerable minute apertures by which every room communicates with the exterior.

Ventilation by propulsion presents several advantages. The amount of air delivered and the rate of movement can be regulated with nicety, and the entering air can be taken from any point desired, can be warmed, cooled by a spray of water, or filtered through muslin or cotton wool in special chambers; and all this can be done at one spot for a number of rooms or buildings.

In the Houses of Parliament at Westminster a combined method of ventilation by propulsion and extraction by heat is in operation. Air is propelled by rotatory fans along conduits to the basement, where it is warmed in winter by passing over steam pipes, and then passes upward through shafts into the space beneath the grated floor of the House. The heat can be regulated by covering the steam pipes with woollen cloths, and in summer the entering air can be sprayed with water or cooled by passing over ice in the conduits. The vitiated air in the House passes through a perforated glass ceiling in the roof, and is then conducted by a shaft to the basement of the clock tower, where it passes into the flue of a large furnace.

In Verity's system, air is set in motion by a spray of

water from a number of very fine jets. The rate of motion can be regulated by the tap which supplies the jet. The method is useful for houses where it is not desired to go to the expense of fans driven by machinery.

In addition to hot-water pipes, the incoming air may be warmed by passing it into firebrick chambers, or through air-ducts, placed behind and at the sides of a fire-grate or stove; or the air may be warmed by conducting it through a tube which passes through the centre of a gas-stove (George's Calorigen and Bond's Euthermic).

The Manchester stove is largely used for schools, hospitals, etc. In this stove the cold air is carried along a shaft placed between the joists of the flooring, and enters a firebrick chamber built into the back of the grate. It then passes through tubes leading from the top of this chamber, and, travelling round the hottest part of the smoke flue, enters the room through openings at the top of the stove. The smoke flue is bent back and carried down the back of the stove, passing under the flooring to the outside, where it is carried up as a chimney.

Practical Examination of the Ventilation of Inhabited Rooms.

In the first place it is necessary to determine the amount of cubic space. In rooms of regular shape this may be done by multiplying together the three dimensions of height, length, and breadth. If the room is irregular in form, containing recesses and projections, or with a raised ceiling, it is usually most convenient to divide it up into a number of simpler parts, whose cubic contents can be determined by some one or more of the following rules:

Area of circle = square of diameter (D^2) × 0·7854.

Circumference of circle = D × 3·1416.

Area of ellipse = the product of the two diameters × 0·7854.

Circumference of ellipse = half the sum of the two diameters × 3·1416.

Area of square = square of one of the sides.

Area of rectangle = the product of two adjacent sides.

Area of triangle = base × $\frac{1}{2}$ height.

Area of a parallelogram = divide into two triangles by a diagonal, and take the sum of the areas of the two triangles.

Area of trapezoid = half the product of the parallel sides × the perpendicular distance between them. A trapezoid is a plane four-sided figure having two of its opposite sides parallel.

Area of segment of circle $= (\mathrm{Ch} \times \mathrm{H} \times \frac{2}{3}) + \frac{\mathrm{H}^3}{2\mathrm{Ch}}$.

(Ch = chord, H = height.)

Cubic capacity of cube or solid rectangle = length × height × breadth.

Cubic capacity of solid triangle = area of triangle × height.

Cubic capacity of cylinder = area of base (circle) × height.

Cubic capacity of cone or pyramid = area of base (circle) × $\frac{1}{3}$ height.

Cubic capacity of dome = area of base (circle) × $\frac{2}{3}$ height.

Cubic capacity of sphere = D^3 × 0·5236.

Thus, supposing it was required to determine the cubic capacity of a circular hospital ward 30 feet in diameter,

with walls 10 feet high, and a dome-shaped roof 5 feet high. The area of the base or floor space is 706·86 square feet. The cubic capacity of the cylinder below the dome is $706{\cdot}86 \times 10 = 7068{\cdot}6$ cubic feet, to which must be added the cubic capacity of the dome $= 2356{\cdot}2$ cubic feet. So that the cubic capacity of the ward is 9424·8 cubic feet.

Having determined the gross cubic space, the next point is to determine the available cubic space, *i.e.*, the gross cubic space less the space occupied by solid objects in the room. Any bulky furniture must of course be measured, and it is usual to deduct 3 cubic feet as the space occupied by each individual, and 10 cubic feet for each bed and occupant. Having made these deductions, the available space for ventilation is arrived at. Next the various openings acting as inlets and outlets respectively must be determined, and thus the area of inlet and outlet provision per head can be ascertained. To distinguish inlets from outlets, observe the direction given to the smoke evolved from smouldering brown paper or cotton-velvet, when held close to the apertures, some of which will be found to act as inlets and others as outlets. The rate of movement of air through these apertures may be approximately ascertained by placing in them an anemometer, which is an instrument consisting of four little revolving sails driven by the wind or current of air. The sails turn an axis with an endless screw running on small toothed wheels, which, by means of a plate and dial, indicate the number of revolutions of the axis and the space traversed by the sails. By experiment with air moving at a known rate of speed, the anemometer may be graduated. It appears, however, that even tested anemometers are subject to variations, and too much reliance must not be placed on their indications. When

the instrument is placed in a ventilating shaft or opening, it should be placed about two-fifths of the distance from the centre to the margin of the opening, that being the situation where the mean velocity is most generally obtained. A modification of the water manometer, or pressure gauge, is occasionally used. The current of air impinges on the surface of the water in one arm of the bent tube, and in proportion to its strength drives the water up the other arm, which is inclined at a certain angle. The records obtained in this manner can be compared with the theoretical velocities arrived at by the use of Montgolfier's formula, allowances being of course made for friction and wind. When the wind is at all strong and is blowing directly into inlet ventilators, or is exerting a powerful aspirating action on chimneys or exit shafts, calculation is useless.

As air enters a room by every crack and crevice, and may even do so through the brickwork of the wall, it is practically impossible to gauge the amount of the incoming air. The best plan is to deduce it from the amount which is leaving the room, as the outgoing air will only leave the room by well-defined channels or outlets. In an ordinary room practically the whole of such air tends to escape by the fireplace, the entrance to the flue of which has generally a transverse section of about 126 square inches. If the rate at which the air is travelling is ascertained by an anemometer, the amount of air leaving the room is easily calculated. Thus, assuming the velocity to be 7 feet per second, then the quantity of air escaping will equal this velocity × the sectional area of the opening (in feet) $= 7 \times \frac{126}{144} =$ 6·1 cubic feet per second, or 22,050 cubic feet per hour. If samples of the air are to be taken for an estimation of

the CO_2, any gas-burners, lamps, etc., which may be alight at the time must be carefully noted.

In any scheme of ventilation, regard must be had to the following practical points:

1. When air is heated it expands and tends to rise; when air is cooled it contracts and tends to fall.

2. Cold air tends to enter a room and to move about very much as water would; and this holds true so long as the temperature of the fresh air remains lower than that in the room.

3. The extent of inlet provision for fresh air is not quite of the same importance as that for the exit of foul air; for if foul air is extracted in sufficient quantities, fresh air will enter somehow to replace it, as by skirtings, crevices in doors, and windows, or even through the brick-work of the walls.

4. While the inlet provision for fresh air should average 24 square inches for each individual, several small inlets not too near to each other are preferable to one large one; and the provision of inlet areas somewhat larger than those of exit tends to minimize draughts.

5. Inlets should be as low in the room as possible, viz., just above the floor (so as not to raise the dust) if the outside air is warm or has been warmed prior to entry, but at a height of about 5 feet if the outside air is cold; otherwise unpleasant draughts are experienced. As a further protection against unpleasant draughts when cold air is admitted, the incoming air should be directed upwards; while hot air, since it tends to rise, should be directed downwards.

6. Outlets should in every case be as high as possible, and preferably close to or in the ceiling; and they should have their extractive powers maintained by means of heat or an exhaust fan, or they are liable to act as inlets.

7. Where practicable, an effort should be made to so place outlets that the vitiated air is drawn towards them before mixing with the general air of the compartment.

8. There is a tendency for fresh air to take a direct course to the outlets, and this must be counterbalanced by a judicious selection of the relative positions of inlets and outlets.

9. Methods of ventilation devised to ventilate *crowded* premises are generally inefficient, unless the incoming air can be warmed in winter to about 60° F.; for efficient ventilation by cold air cannot be tolerated, and there is a great tendency among workers to close all ventilating inlets.

10. With less than 250 cubic feet of space per head, no ventilation can ever be satisfactory which is not aided by mechanical force.

11. The source of the incoming air should be considered. It should not be borrowed from adjoining rooms, but taken direct from the outside. One great advantage of the more expensive mechanical system of ventilation is the fact that sufficient air can always be obtained from a source which is known and selected.

12. Ventilation dependent on the extraction of foul air is more convenient and satisfactory than that in which propulsion is mainly relied upon; but the purity of the air is not so easily provided for or guaranteed.

13. If warmed air is forced into a room, it should only be raised to a temperature sufficient to prevent a feeling of cold (about 60° F.). More highly heated air is often felt to be overdry and unpleasant.

14. The heating of the room should be effected by fires, stoves, or pipes in the room itself, and should not be made to depend upon the warmth of the incoming air.

15. It is difficult and expensive to apply methods of mechanical ventilation to old premises.

CHAPTER IV.

WARMING AND LIGHTING.

Warming.

Individual susceptibilities to heat and cold are various, depending as they do upon age, sex, robustness of constitution, and previous habitude. It may, however, be permissible to state that, as a general rule, the temperature of a sitting-room or workroom should be about 60° F. to 65° F.

Radiation.

In this country houses are generally warmed by radiant heat from open fireplaces. By radiation is meant the passage of heat from warm bodies to colder ones, the rays of heat passing through the air, but without warming it. This form of heat is no doubt the most healthy, for whilst objects within the range of the fire are heated, no impurities are added to the air of the room. It is, however, extremely wasteful, for the greater part of the heat (five-eighths at least) escapes up the chimney; of the remaining heat, about two-eighths warms the surfaces of walls, floors, etc., in the room, and one-eighth warms the air. The column of air in the chimney flue is heated, and, becoming lighter than the external air, escapes at the roof of the house, to be replaced by colder and denser air from below.

The intensity of radiant heat is inversely as the square of the distance of the heated object from the source of heat. Thus, if there are two objects, 1 foot and 3 feet distant respectively from an open fireplace, the more distant object only receives one-ninth the amount of heat received by the nearer object. This fact shows the impossibility of warming equally all parts of a room, when the source of heat is an open fireplace.

Of late much has been done to improve open fireplaces by securing the greatest amount of heat production with the least consumption of fuel. Some of these improvements have been made at the suggestion of Mr. Pridgin Teale. They may be thus summarized: The width of the grate at the back should be about one-third the width in front facing the room, the sides of the grate being splayed out at the necessary angle. The back and sides of the grate should be formed of fireclay, and the back, instead of rising perpendicularly, should be "rifle-backed," *i.e.*, curved forward so that the flames may play upon it (Fig. 30). The curved portion becomes heated by some of the upward rays, which would otherwise be lost up the chimney, and radiates this heat into the room. Vertical fire-bars are said to allow more heat to radiate into the room than horizontal bars.

The floor of the grate should be formed of a solid slab of fireclay; or if the lower fire-bars are retained, a shield should be placed on the hearth, rising as high as the bottom bar of the grate, so as to form a hot-air chamber under the grate completely closed off from the air of the room (Fig. 30). The object of this arrangement is to check the bottom draught under a fire, which causes too quick combustion and waste of fuel.

The whole fireplace should be brought well forward into the room, the grate being placed low down near the

floor, and the chimney throat should be narrowed as much as possible. A movable hinged canopy, to regulate the draught up the chimney, is a desirable arrangement.

Open grates of this description create much smoke, as the combustion of the fuel is by no means complete. Attempts have been made to construct a smokeless open grate; and the plan which has been found on the whole to answer the best is to "underfeed" the fire, by which is meant that the supply of fresh fuel is introduced beneath the incandescent coal which forms the top of the fire, and through which the smoke arising from the fresh coal must pass, thus securing complete combustion.

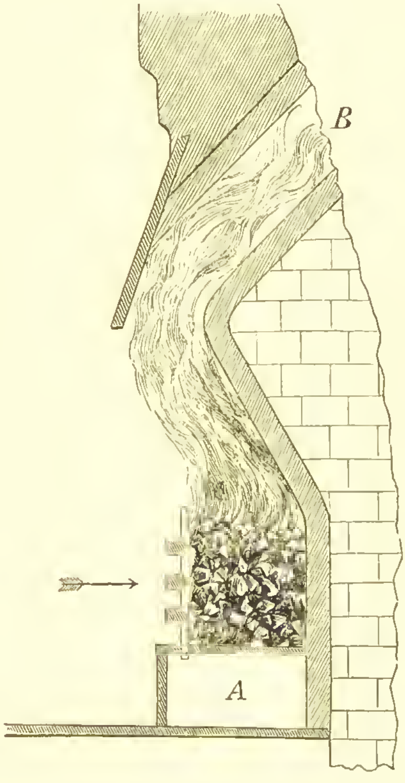


FIG. 30.—RIFLE-BACK STOVE WITH ECONOMIZER.
A, Hot-air chamber; *B*, flue.

In one of the best of these smokeless fireplaces a curved ledge projects from the bottom of the grate. The fresh fuel is placed on this ledge and forced under the blazing coal above by means of a special kind of shovel. These "underfed" grates are found to be very efficient heaters for the amount of coal consumed, and they continuously expose a clear fire free from smoke, but they require more care in stoking and management than ordinary grates.

Wherever possible, fireplaces and chimney flues should be built in one of the inner walls of a house. The waste heat of the flue will then serve to warm the upper rooms at least, and the total loss will be less considerable than in the case of fireplaces built in an outer wall. It is evident that, as open fireplaces act as ventilators for extraction of air, to carry on this function the column of air in the flue must be kept continuously heated; otherwise the chimney will not "draw," and back-currents of smoke enter the room. In an ideal stove, the heat escaping up the chimney should be not more than sufficient to maintain a good draught, the rest being radiated into the room.

With a reduction in the price of coal gas, open gas fires have come more largely into use. As usually constructed, the flames from a row of Bunsen burners play upon asbestos in lumps or fibre, which is heated to a red heat. Until gas is supplied at 1s. or 1s. 6d. per 1,000 cubic feet, which could easily be done if it were freed from illuminants, or until a public supply of *water gas* is made safe and available, gas fires must be more expensive than coal. But they have the advantage of being very cleanly—there is no soot in the chimney flue and no dust or ashes—very convenient, and of causing no trouble. As regards the prevention of smoke, the more extended use in our large towns of coal gas for heating and cooking would undoubtedly tend to free the air from much of the soot and smoke that now pollute it. Fogs, which depend so largely upon climate and site, would be just as frequent, though less sooty and yellow. They would also be less sulphurous, for the sulphur compounds produced by gas combustion are less than those produced by coal.

It is probable that *water gas* would come largely into

use for heating and illuminating purposes—for gas fires and gas cooking stoves, and for incandescent burners—were it not dangerous, from containing such a large percentage of carbonic oxide. Water gas is produced by blowing steam through incandescent coke or other carbonaceous matter, raised to a high temperature in a "generator" furnace by the aid of an air-blast. The incandescent coke gives off what is known as "producer gas," and this is led away from the generator before the steam is introduced. The introduction of the steam is only continued for about four minutes, after which time it is necessary to turn on the air-blast again to reheat the coke. It will thus be seen that the process consists of alternately blowing the generator hot (for ten minutes), when producer gas is formed and led away, and of making water gas by introducing steam over the hot fuel (for four minutes). In this way the water is split up into hydrogen and oxygen: the hydrogen remains free, and the oxygen with most of the carbon forms carbon monoxide, the mixture being "water gas." The water gas, as formed, is passed over scrubbers and purified over oxide of iron, in much the same way as coal gas, before being stored in gas-holders; it then consists of hydrogen gas (about 35 per cent.) and of carbonic oxide (25 to 35 per cent.), marsh gas 20 per cent., and 10 per cent of ethylene, etc. In heating power water gas is far superior to coal gas; and as the only products of combustion are H_2O vapour and CO_2, the injurious sulphur products of combustion of coal gas are avoided. Water gas, too, can be produced very cheaply, viz., at about 4d. per 1,000 cubic feet. The "producer gas," consisting largely of carbonic oxide, is used for heating the boilers which generate the steam. The large quantity of CO in water gas causes it to act as a powerful poison, and yet, from being odour-

less, escapes, if they occur, are not at once detected. For lighting purposes the gas is "carburetted"—that is, enriched by hydrocarbons derived from oil. This carburetted water gas smells much like coal gas; its candle power is greater, and it is, on the whole, cheaper to make. It has been adopted for lighting purposes in many towns in America, and it is often used, and mixed with coal gas, in this country. A recent Departmental Committee recommended a statutory limit of 12 per cent. of CO in any illuminating gas; for an escape leading to the presence of 0·4 per cent. of CO in the general atmosphere may prove fatal.

It is, perhaps, needless to point out that plumbers should never be allowed to fix a gas fire, or, in fact, any gas-consuming appliance (such as a bath-heater or "geyser"), which burns more than 5 feet of gas per hour, without providing a chimney flue to carry off the products of combustion to the outer air.

Ventilating grates may be combined with open fireplaces. The usual method is to construct a chamber lined with fireclay at the back and sides of the fireplace, and extending up behind the chimney flue. An opening below admits fresh air from outside the house into the chamber; here it is warmed and escapes by an opening into the room above the chimney-piece, where it mixes with the current of air at this spot, flowing up towards the ceiling. Galton's Grate and the Manchester School Grate act upon this principle.

Conduction and Convection.

By conduction heat passes from one molecule of air to another in contact with it, but, as air is a very bad conductor of heat, the process is very slow. The conveyance

of heat by means of the movements of masses of heated air (convection) is the most effectual agent for heating. Air when heated expands, and becomes lighter bulk for bulk than an equal volume of colder air, so it rises upwards, its place being taken by the colder denser air.

Houses may be heated by means of stoves in which coal, coke, gas, or oil is burnt, by hot-water pipes, and by steam pipes. The air coming in contact with the heated surfaces is warmed, expands, and rises, and is replaced by cold air to undergo a like process. In this way currents of air circulate about a room, which tend to heat every part of it equally. The most satisfactory way of uniformly heating the living rooms of a house is by warming the air of the hall landing by means of hot-water pipes or a ventilating stove placed in the hall. The warm air which ascends can then be admitted to the rooms above the ground-floor, by openings over the doors, which openings may be fitted with valves.

The great distinction between stoves and open fire-places is seen to be that, whilst in the latter the heated air escapes up the chimney, in the former the air, heated by contact with the stove, circulates through the room.

There is an immense variety of different kinds of heating stoves, but they may all be classified under *close* stoves and *ventilating* stoves. In the former kind no arrangements exist for providing fresh warmed air; whilst in the latter fresh air from outside the house is made to circulate through the stove, without coming into contact with the products of combustion, and is, when warmed, allowed to enter the room. Bond's Euthermic Stove is one of the best forms of ventilating stove. In this the fresh air from the outside is conveyed to and warmed in a central upright tube, which communicates with the room at the top of the stove. Surrounding

this central tube is a larger external one, open below, where gas-jets are kept burning, and communicating above with a flue. Thus, not only is warmed fresh air supplied to the room, but foul air is also removed along with the products of combustion between the inner and outer tubes. In all stoves economy of fuel is aimed at, by providing doors and dampers to shut off the draught and make the combustion as slow as possible; and the flues are often carried horizontally for some distance, in order that a part of the waste heat may be utilized. It is evident that the slower the combustion and the more complete the utilization of the heat of the burning fuel in warming the room, the less does a close stove act as an exhaust ventilator; and economy of fuel and utilization of heat are purchased at the expense of healthiness.

The ventilating stoves which introduce a supply of fresh warmed air are decidedly more healthy; but there are certain disadvantages in the use of stoves of all kinds which require consideration.

In the first place, stoves are apt to render the air of a room too dry. There is the same amount of moisture in a cubic foot of the heated air as in the cold air before it is warmed; but the relative humidity of the heated air is greatly diminished, as hot air is capable of holding more moisture, before saturation is reached, than cold air; and it is upon relative humidity that health and comfort depend. This defect may, to a certain extent, be overcome by placing vessels of water in the room or on the stove. Another disadvantage of stove-warmed rooms is that the air is often at a higher temperature than the walls and floors of the apartment. As a consequence chills are often experienced, the bodies of the occupants radiating their heat to the cold surfaces around them, whilst the defensive forces of the body against chill are

relaxed by the enervating warmth of the stove-heated air.

Secondly, if the stove becomes overheated, the organic matters in the air become charred by contact with the heated surface, and a disagreeable close smell is perceived.

Lastly, the presence of carbonic oxide—a most poisonous gas—has been detected in the air of stove-heated rooms, more especially when the stove is of cast iron. Either this gas passes out of the furnace through invisible fissures in the cast-iron plates and joints, or it traverses the walls of the stove at a red heat. Others suppose that the gas may be formed by incomplete combustion of particles of carbon or organic matter floating in the air, when brought into contact with the hot metal.

Cast-iron stoves are very liable to become overheated, as, being good conductors, they rapidly heat and cool. In such stoves, therefore, the heating surface should be increased by vertical flanges projecting from the top and sides, by which means the heat, being conveyed to a larger surface, is less intense, because cooling is more rapid. It is safer not to use cast-iron stoves at all, unless lined inside with fireclay, which, being a good non-conductor, prevents the over-rapid heating of the iron walls, and the warming of the room is altogether more equable. There are many stoves now made entirely of fireclay and china, with arrangements for the supply of warmed fresh air at an agreeable temperature of about 70° F. They are especially valuable for heating halls and public buildings.

No ill effects appear to follow upon the use of oil stoves in living-rooms, if the combustion of the oil is complete and there is efficient air renewal in the room,

despite the absence of flues to convey away the products of combustion.

Steam pipes are largely used for heating factories and workshops and public buildings where steam power and waste steam are at hand.

Two kinds of hot-water pipes for heating purposes are in use. In the low-pressure system, 2 or 3 inch cast-iron pipes are connected with a boiler so as to provide a complete circulation. The water is heated in the boiler, circulates through the pipes, parting with some of its heat to the air in contact with them, and returns again to the boiler, the circulation being due to the difference between the specific gravities of the water in the ascending and return pipes. From the highest part of the system, a small escape pipe, to give vent to steam and hot air, must be carried into the outer air. The water circulating in such a system never acquires a temperature exceeding 200° F. or thereabouts.

In the high-pressure system (Perkins') the pipes are of welded iron with thick walls and ½ inch internal diameter. A coil of the pipe, of about one-sixth of the total length, passes through the furnace, no boiler being required. The expansion of the water is provided for by a larger pipe, capable of holding from 10 to 15 per cent. of the water, fixed at the highest point in the system. The water, being under pressure, can be heated to 300° or 350° F.

It is estimated that 12 feet of low-pressure piping is equivalent for heating purposes to 8 or 9 feet of the high-pressure piping.

Soft water is far preferable to hard water for use in boilers and hot-water pipes. The lime deposit from hard water gradually narrows the calibre of the pipes, which in time may become completely blocked. In

boilers, the lime deposit forms a non-conducting lining, which obstructs the passage of heat to the water, and is a frequent cause of explosion, especially in kitchen boilers. When the fur lining is thick, the iron boiler-plates become red hot from the heat of the fire; and should a crack in the fur suddenly form, the water, coming in contact with the red-hot metal, is converted into steam with explosive violence. Another cause of explosion in kitchen boilers which are not connected with a hot-water cistern, or are unprovided with a steam escape pipe, is the blocking of the pipe which supplies cold water to the boiler. This occasionally happens after a hard frost, if the pipe is unprotected.

Lighting.

The illumination of a room is a matter greatly affecting the comfort, if not the health, of the occupants, and is of especial importance in the case of factories, workshops, and schools, where the eyesight is concentrated on small objects for many hours at a time.

Artificial Lighting.

The most commonly employed method of obtaining an artificial illumination is the combustion of inflammable vapours producing a flame. Coal gas, petroleum and colza oils, and candles, are well-known examples of this form of illumination. In the electric light, on the other hand, there is no combustion, or only to a trifling extent; but light is emitted from a substance raised to a high temperature and a state of incandescence by the passage through it of an electric current.

The inflammable gases and vapours are chiefly compounds of carbon and hydrogen, without oxygen in coal gas and vaporized petroleum oils (marsh gas, olefiant

gas, acetylene, naphthalene, propylene, and benzine), and combined with oxygen in colza oil.

When these inflammable vapours are heated to a sufficient temperature, the hydrogen combines with oxygen to form water vapour, and an intensely hot flame without luminosity is produced; the carbon particles, which are liberated in a state of very fine subdivision, are rendered incandescent by the heat of the hydrogen flame, and they combine with oxygen to form CO_2 and traces of CO. The luminosity, which is situated in the outer portion of the flame, is due to the incandescent carbon, whilst the inner portion—the hydrogen flame—is almost non-luminous. The products of combustion are chiefly water vapour and carbonic acid. The light is very deficient in the blue and violet rays of the solar spectrum, and has therefore a yellow or orange colour. Hence the true colours of objects illuminated by a flame are not perceptible.

Coal Gas.—The principal illuminant of coal gas is heavy carburetted hydrogen or olefiant gas (C_2H_4). There are also present other hydro-carbons—*i.e.*, benzene, propylene, naphthalene—which are illuminants. The heavy hydro-carbons, if burned by themselves, would yield a smoky flame, but these are suitably diluted in coal gas by hydrogen, marsh gas or methane, and carbonic oxide, which together form some 90 per cent. of the coal gas. When the gas is burnt, the hydrogen or hydro-carbons are almost destroyed, and the products are approximately: Nitrogen 67 per cent., water 16 per cent., carbonic acid 7 per cent., carbon monoxide 6 per cent., and traces of sulphurous acid and ammonia.

Coal-gas illumination was a great advance on the candle illumination of a former period, but it has certain

drawbacks. There is the danger of escape of gas from mains and pipes into the houses, forming, if the escape is large, explosive mixtures with the oxygen of the air; or if small, creating a serious pollution of the atmosphere. The products of combustion, the carbonic acid and sulphurous acid from the sulphur compounds in coal-gas, are injurious to health, and destructive to books, furniture, and pictures indoors, and to building stones and mortar out-of-doors. The combustion also heats the air and dries it; for although watery vapour is one of the products, the relative humidity at the higher temperature is less. Finally, unless the supply of gas and air is carefully regulated during combustion, the gas is wasted, the light is lessened, and unconsumed particles of carbon are given off which deposit as soot on adjacent surfaces.

The burners in common use are: (1) The *fish-tail* or *union-jet*, which has a flat steatite top, slightly depressed in the centre, through which two small holes are bored in directions inclining towards one another from below upwards. The two streams of gas meet and produce the flat flame usually seen. (2) The *batwing* has a hemispherical steatite top, through which a vertical slit is cut for the gas to issue. The flame is flat and semicircular. The flames from these two burners require no chimneys, but are usually enclosed in globes to soften the light. (3) The *Argand* burner is a small ring or cylinder pierced at the top with fine holes for the issue of the gas. The flame is a hollow cylinder, and the air has free access both to its interior and exterior. The flame must be enclosed in a chimney, in order that the supply of air to it may be regulated.

The Argand burner has been improved by Silber, Sugg, and other manufacturers. These improvements are directed, first, to cause the issue of the gas from the

burner at the lowest possible velocity, and, secondly, to divide and regulate the air-supply both to the outside and inside of the flame, and to direct a part of it to the higher portions of the flame, where perfect oxidation of the carbon is most required. These improved Argands give a far better and steadier light than the flat flame burners, for the same consumption of gas.

There are several *ventilating burners* which remove the products of combustion of the flame through a flue to the external air, and also serve to remove the heated and vitiated air from the top of the room or hall. The *sunlight* burners used in theatres, and the *globe* light are examples of these.

In the *regenerative gas-burner* of Siemens, the air and gas, previous to their union, are heated in a chamber surrounding the flue, by the heat of the products of combustion. The flame, which is in the form of a hollow cylinder, like the Argand flame, burns around a short tube of porcelain. This tube is the commencement of the flue, and the flame, owing to the draught, turns over the top of it, and the products of combustion pass up the flue through the centre of the regenerative chamber, and finally into the external air. This form of burner is very useful where a powerful light is required, as in streets, squares, halls, and public buildings. The smaller sizes do not give equally good results.

The Welsbach *incandescent gas-burner* is a recent invention, which promises to have a very extended use. It consists of a Bunsen burner, with a cap (mantle) of asbestos gauze material rendered non-inflammable by chemical treatment with sulphate of zirconium, suspended in the non-luminous flame; the flame, although non-luminous, is intensely hot, and the gauze mantle becomes incandescent and gives a brilliant light, far

whiter and steadier than the ordinary gas flame. The flame should be enclosed in a chimney. The illuminant power is very high for the gas consumed, and the heat given off is far less than with an ordinary gas flame burning the same amount of gas. If such burners came into general use, a cheap form of gas containing no illuminants could be supplied; for heat and not light is required in the flame. The cheap gas would also lead to a more general adoption of gas heating and gas cooking, and to the partial solution of the smoke question.

In the *albo-carbon* light, the vapour of naphthaline is burnt in the coal gas, and a brilliant white light is produced. The naphthaline, which is solid at ordinary temperatures, is placed in a reservoir connected with the gas-burner, and this reservoir must be heated by a small gas-jet or by strips of metal extending from the flame. The vapour of naphthaline must not be allowed to escape into the air, as its odour is most offensive.

One cause of waste and imperfect combustion with flat flame burners—which are more largely used still than any of the improved forms—is the constant alterations in pressure in the gas-pipes and mains. At one period of the day the pressure may be less than one inch of water, whilst at another it may be 3 inches or more. Consequently the flat flame, which is steadily burning under the low pressure, at the high pressure is flaring and singing; more gas is issuing from the burner than can be perfectly burnt, and unconsumed carbon is given off from the flame to pollute the air and blacken everything around.

To control these variations in pressure, gas-governors or regulators are employed. In the larger form, the governor is fixed close to the meter, and controls the pressure throughout the house pipes; whilst a small form

is made as part of each individual burner. The best kinds of governor act automatically; by the action of valves an increased pressure narrows the lumen of the channel through which gas passes, and a diminished pressure widens it. Single burner governors are also found to answer fairly well. *Acetylene gas*, generated by the action of carbide of calcium on water, furnishes a powerful white light; but its use, when generated and stored in the house for consumption in hand lamps, is attended with danger, unless great care is exercised.

Petroleum Oils.—By the distillation of crude petroleum oil obtained from wells and borings, an oil suitable for burning in lamps—commonly called crystal oil or kerosene—is obtained. In the distillation, a volatile spirit, benzoline, and the heavy oils, some of which are solid from containing paraffin, are also obtained, and are separated from the lamp oil.

Lamp oil contains the hydro-carbons previously mentioned, and gives off an inflammable vapour which at a certain temperature takes fire. This temperature varies for different specimens of oil, and is called the "flashing-point."

A Select Committee recently appointed by Parliament attributed the chief danger of explosion to cheap lamps of defective design, and they recommended that the flash-point (Abel close test) should be raised from 73° F. (the limit defined by the Petroleum Act, 1879) to 100° F.; that statutory powers should be created to enable the Secretary of State to issue orders affecting the manufacture and sale of lamps; and that information should be spread among the public as to the nature of petroleum and the management of lamps. In the suggestions issued by the London County Council, it is pointed out that the flashing-point of ordinary petroleum oil is a little above 73° F., that the

oil in the reservoirs of lamps is rarely heated above 100° F., and that the best safeguard against accident is therefore never to burn oil which has a flashing-point of less than 100° F., which oil should be sold as cheaply as low-flash oil. Lamps, too, should be strongly made, and kept thoroughly clean ; especially should the reservoir and burner be strong ; the latter should screw into the collar, and its base should be broad and heavy. The wick should be soft, and just fill the wick tube ; it should be frequently renewed, and before being put into a lamp it should be dried at a fire, and immediately soaked with oil. The reservoir should be filled with oil before the lamp is lit, and the burner made clean before lighting ; the wick when lit should be partially turned down, and then gradually raised ; the wick should not, however, be left turned down ; lamps that have no extinguishing apparatus should be put out by turning down the wick until there is only a small flickering flame, and a flat piece of metal should then be placed on the top of the chimney, so as to close it entirely ; finally, cans or bottles used for oil should be free from water and dirt, and kept closed.

Owing to improvements in lamps, and to the prohibition of the sale of highly inflammable oils, the danger of explosion is now slight. As regards lamps, explosion may occur when, from any cause, the vapour over the oil in the reservoir comes in contact with the flame of the lamp, as through defects in the lamp or by blowing down the chimney through an ill-fitting wick, etc. But the best duplex lamps (the Defries and other safety lamps) are now sold with extinguishers, and with an ingenious arrangement by which, if the lamp is overturned, the flame is immediately extinguished.

Lamp accidents often appear to arise from the use of cheap lamps of defective design, leading to a leakage of oil

through imperfect connections and fittings. The oil may thus become ignited. Sometimes the lamp is upset from its instability, or broken owing to the fragile character of the reservoirs.

Colza oil does not give off any inflammable vapour, but it is much dearer than kerosene, and the illuminating power is less. Colza oil lamps require more care in trimming than kerosene lamps.

The relative cost of candles, kerosene, colza, and coal-gas, to produce the same illuminating effect, is seen from the following figures:—To give a uniform light of twenty standard sperm candles for 100 hours, the candles would cost £4 5s. 9d.; colza oil burned in moderator lamps with Silber burners would cost 5s. 9d.; petroleum oil burned in Silber burners would cost 2s.; and coal gas burned in an improved Argand would cost 1s. $9\frac{1}{2}$d., with gas at 3s. 4d. per 1,000 cubic feet.

Kerosene, like coal gas, gives off sulphurous acid when burned, but colza oil does not. Candles, especially the cheaper kinds, give off much unconsumed carbon, by reason of their low melting-point admitting of volatile products being given off before the fats reach the flame and are properly consumed.

Electric Light.—The electric light presents the following advantages over coal gas, oil, and candles. There is no consumption of oxygen, there are no products of combustion to pollute the air, and the heat produced is relatively slight. The light of the arc light is not yellow, but white. It precisely resembles solar light in being rich in the violet and the ultra-violet rays. Plants grow and flower, and fruit ripens, when exposed to this light, just as they do in the sunlight, whilst photographs can be taken as easily by the arc electric light as by daylight.

The electric current can be produced by batteries,

accumulators, and dynamo-machines, and is conveyed in copper wires to the spots where illumination is required.

In the arc light, which is suitable for lighting streets, squares, and large halls and buildings, the illumination is produced by the passage of the current through two carbon rods brought into close apposition. The resistance offered to the passage of the current across the space intervening between the points of the carbon rods creates sufficient heat to cause the carbon points to become brilliantly incandescent. The light is extremely dazzling, and is productive of injurious effects on the eyes of those who are much exposed to its influence.

The incandescent lamps are best suited for domestic use. In these the current is passed through a loop of filamentous carbon enclosed in a small glass globe exhausted of air, or filled with some gas, such as nitrogen, which does not support combustion. The resistance offered by the carbon to the passage of the current raises it to a white heat.

The extent to which different modes of lighting affect the atmosphere may be thus represented :

	Amount consumed.	Candle-power.	Oxygen removed.	CO_2 produced.	Heat calories produced.
Tallow candles ..	2,200 grs.	16	10·7 c. ft.	7·3	1,400
Sperm candles ..	1,740 ,,	16	9·6 ,,	6·5	1,137
Paraffin oil lamp ..	992 ,,	16	6·2 ,,	4·5	1,030
Kerosene oil lamp ..	909 ,,	16	5·9 ,,	4·1	1,030
Coal gas, No. 5 bat-wing burner ..	5·5 c. ft.	16	6·5 ,,	2·8	1,194
Electric incandescent	—	16	0·0	0·0	37

The Welsbach incandescent gas-burner is hygienically by far the best form of lighting by coal gas.

School Hygiene.

The best shape for a schoolroom is an oblong, with the windows in one of the longer sides only. There

should be no windows on the opposite side, for cross-lights are better avoided, although some authorities think cross-lights are not injurious. The area of the windows, clear of sash-frames, should be not less than one-tenth, and not more than one-fourth of the floor area of the room. The windows should reach as high as the ceiling of the room, and open directly into the external air. Double windows economize heat, keep out noise, and may be made to help ventilation.

The school-desks should be arranged parallel with one another, but at right angles with the windows, and wherever possible the desks should be placed in the space intermediate between two windows. To avoid shadows when writing, the scholars should sit with the left hand nearest the windows, so that the illumination of books and lessons may be from the left front. There is then plenty of light on the objects on the desk, but the rays are not reflected directly into the eyes of the scholars, as they are in front illumination with desks facing the windows. The height of the sills from the floor should never be less than 5 feet.

The defective lighting in schoolrooms is one of the chief causes of short sight. The child, not being able to read its book when placed at the proper distance (15 inches) from its face, stoops over the desk to lessen the distance; the eyes converge when brought too near the object, and the muscular strain thus induced causes a gradual elongation of the antero-posterior axis of the eyeball, with the production of myopia; *i.e.*, the image of the object seen forms in front of the retina, and is blurred and indistinct unless the object itself is very close to the eyes. Imperfect lighting leads to the use of artificial light, with its attendant vitiation of the atmosphere. Daylight reflectors sometimes suffice to remedy the evil.

As subsidiary factors in the prevention of visual defects in children, the following are important :—The type of school-books should be large and well defined ; for the school-books of very young children pica type should be used, and for those of older children small pica—not bourgeois or minion ; the desk should slope at an angle of about 30° for writing, and 40° for reading ; the height of the seat from the ground should equal the length of the scholar's legs from the sole of the foot to the knee ; the depth of the seat from front to back should not be less than 8 inches ; the distance of the front of the seat from a perpendicular line let fall from the edge of the desk should be not more than 1 inch, or may be 0 ; and the perpendicular distance of the seat from the edge of the desk should be one-sixth the height of the scholar (Newsholme). To meet these requirements there should be three sizes of desks in each large class-room. The seat should be provided with a straight back and curved pad or cushion 3 inches broad to fit into and support the small of the back and loins. In this way the most comfortable positions may be obtained for reading and writing, and the drooping of the head from weariness, which brings the eyes too close to the book, is avoided. Bad desks and seats also lead to compression of the thorax, interfering with free expansion of the lungs ; and the relaxation of muscles leads to round shoulders, spinal curvature, and fatigue. For young children the lesson hours should be broken by frequent short intervals for play, and the proper ventilation, warming, and artificial lighting of the room require careful attention. The temperature of a class-room should be between 60° and 65° F. ; excessive heat relaxes, causing languor and unfitness for work.

Some system of artificial ventilation with a supply of

warmed fresh air is especially necessary for schoolrooms, where the amount of cubic space per head is often very limited. The English Education Department requirements are only 100 cubic feet of space per scholar, and 10 square feet of floor space. These are the minimum requirements; but even with double these amounts, ventilation by natural means in cold weather would be productive of draught and great lowering of temperature in the room. Dr. Newsholme is of opinion that good average requirements for schools are, for each scholar, 150 cubic feet of space, 15 square feet of floor space, and 1,500 to 1,800 cubic feet of fresh air per hour.

The walls of a schoolroom should preferably be painted or tiled, so that they can be washed, and any colouring should be pale and subdued; all projections (cornices, etc.) which can harbour dust should be avoided so far as possible.

The best floors are made of hard wood in narrow planks, with dovetailed or matched joints; these may be beeswaxed and polished at intervals, and should always be swept daily.

All staircases should be wide and fireproof, and faced at the ground-floor by a wide door, opening outwards towards the street. The cloakroom must be capacious, and the pegs for hanging clothes should be at sufficient intervals to allow of the clothes hanging without touching each other.

Covered sheds should be provided for recreation when it rains; and if space is unprocurable on the adjoining ground, a basement or a flat roof may be designed to meet the purposes of a covered playground.

Urinal accommodation to the extent of at least five places for every 100 children should be provided, and at least one water-closet seat for every fifteen girls or twenty-

five boys. A trough water-closet is a very suitable form for schools, but the flushing provision must be adequate and systematically regulated.

All dormitories must be well lighted and ventilated, and at least 400 to 500 cubic feet of space should be allowed for each scholar.

CHAPTER V.

SOILS AND BUILDING SITES.

THE health of a locality is intimately connected with the nature of the soil on which the houses are built. It is generally believed that the most porous soils—the gravels and sands—are the healthiest, because they are the driest, and this view is in the main correct; but owing to their porosity they are readily polluted by leaky drains and cesspools. It will be advisable, however, to consider in some detail the conditions which affect the healthiness of the different soils, and subsequently to describe the precautions that must be taken when houses are being built, to obviate such conditions as are likely to be injurious.

The porous or permeable soils—the loose sands and gravels and the sandstones—are capable of holding considerable volumes of air or water. Even the impermeable rocks—the granites and metamorphic rocks, the dense clays and hard limestones and dolomite—are not wholly unabsorbent, but comparatively speaking they may be looked upon as impermeable. Between these and the porous sands and gravels are all stages of gradation. The surface soils which usually lie upon the denser kinds of rocks, of which they are to a considerable extent the weathered fragments, are always more or less porous. The interstices or interspaces between the particles of the

porous soils are necessarily occupied by air (ground air), or at a varying depth by water (ground water). When there is air as well as water between the interstices, the water is nothing more than "ground moisture," but when the interstices are completely filled with water, then the level of the ground water has been reached. The ground water is derived from the rain which percolates until it reaches a stratum of rock sufficiently dense to prevent it penetrating any further. Above the level of this subterranean water the interstices of the soil are mainly filled with air.

The depth at which water will be reached in any soil depends on a variety of circumstances—the elevation above the surrounding country, the depth of the impermeable stratum from the surface, and the ease with which the underground water moves towards its natural outlet in spring, river, or sea. In the low-lying plains and valleys, the underground water is not, as a rule, far from the surface of the earth. Its level is not constant, as we have seen in the chapter on Water (p. 25), but is always changing. After heavy rainfall the level may rise ; and there is usually a periodic rise, commencing in the late autumn, and a corresponding fall in the spring, due, as explained before, to the increased percolation of the rainfall in the colder months of the year, and its cessation in the warmer. The lateral movement of the ground water is generally towards the nearest water-courses, the sea, wells, fissures in rocks, shafts of coal-mines, etc.

The movements of the ground water cause corresponding movements in the ground air which lies above it. As the ground water rises, it occupies the space formerly occupied by the ground air, and the latter is slowly expelled from the surface of the earth : as the ground

water sinks, air is sucked in to occupy its place, to be again expelled when the water rises. There are other factors influencing the movements of the ground air which have no effect on those of the ground water. The principal of these are, alterations in barometrical pressure, sudden variations in temperature, and the action of the wind forcing air into the strata which are opposed to its path. It is thus seen that the surface layers of the earth act as a sort of lung, slowly taking air in and slowly expelling it again.

This action is no doubt greatly increased in the small surface of ground covered by a house. In winter, when the surface of the ground may become ice-locked, the heat of the building and the aspirating action of fires must tend to draw air in large volumes through the surface of the soil, unless the site is covered with an impenetrable layer of asphalt or cement concrete. The ground air is generally moist and always impure. The amount of moisture depends on the proximity of the ground water to the surface of the soil; if this is but a few feet from the surface, the ground air is saturated with moisture; but if at great depths the moisture is not excessive. The ground near the surface of the earth in most parts of the world is damp, even after the most prolonged drought, owing to capillary attraction and evaporation from the surface of the ground water, and to the alternate risings and fallings in its level.

The impurity of the ground air is due to the decomposition of the various organic matters which are washed into the soil by the rain, or which are naturally present in some soils (alluvial and marshy). These latter are usually of vegetable origin. The impurity of the ground air in virgin or natural soils is shown by the great diminution in oxygen and the enormous increase in

carbonic acid which characterized the samples that have been examined. In the neighbourhood of houses, however, the foulness of the ground air is due to animal contaminations chiefly, and these often of the most dangerous description. Leaking cesspools, sewers, and drains allow animal filth, and possibly infected excretions, to pollute the water and air in the soil; graveyards and cemeteries permit the exhalations from decomposing animal bodies to exercise a similar pollution; whilst the organic effluvia arising from *made* soils—soils formed of house refuse and dry rubbish—too often seriously imperil the health of the inmates of the houses built over them.

The organic matters, whether of vegetable or animal origin, are decomposed in the soils chiefly by bacterial organisms. These organisms grow in the presence of such food material, breaking it up into simpler combinations—carbonic acid, ammonia, and water—and thus by the processes of fermentation and putrefaction exert a purifying action, and at the same time convert the complex organic bodies into products best fitted to be assimilated by the growing vegetation on the surface of the soil. The presence of oxygen, warmth, and moisture are essential to the proper carrying out of these fermentative processes. Oxygen is present in the ground air, moisture is derived from the ground water, and the temperature of the soil is usually suitable, except during long frosts or in very cold climates. The nitrifying action of the bacterial organisms is an especially important one, and has been more fully alluded to in a previous chapter.

It is thus seen that surface soil acts as a vast natural laboratory for the purification and utilization of effete animal and vegetable matters. Even in the purest virgin soils the ground is impure, and in the polluted soils of

towns and villages it is likely to be contaminated with noxious effluvia from decomposing animal filth. Hence the importance of preventing the entrance of ground air into houses, which may be accomplished by covering the entire site over which they are built by a layer of cement concrete, asphalt, or other impermeable substance.

The draining of damp soils, so as to permanently lower the level of the subsoil water, is also a measure much needed in the interests of health, but of which the utility is not so immediately apparent as in the case of the exclusion of ground air. In the first place, it is desirable to avoid great fluctuations in the level of the ground water; and this can, to a certain extent, be accomplished by subsoil drainage, which at once carries off the water when it rises to the level at which the drains are laid. When the subsoil water rises, it forces the ground air before it and out of the soil; not only this, but it causes, when it arrives within a few feet of the surface, a dampness of the atmospheric air by evaporation, and consequently a cooling of the air. The moisture ascends by capillary attraction into the walls of houses, to be subsequently evaporated from the surfaces of the internal walls; in this evaporation heat is absorbed from surrounding objects, and the air of a house with damp walls is not only moist, but cold.

This condition of dampness and moisture in the site and air of a house is one credited by universal experience with the production of rheumatism, catarrh, neuralgia, and all affections of a bronchial and pulmonary nature, and is probably a strong predisposing factor in the production of outbreaks of diphtheria. Dampness of soil is also favourable to measles and whooping-cough.

The researches of Dr. Bowditch, of Boston, U.S.A.,

and of Dr. Buchanan in this country (9th and 10th Reports, M.O.P.C., 1866, 1867), have conclusively shown that there is an intimate connection between moisture of soil and destructive diseases of the lungs (diseases of the lungs attended with destruction of lung tissue, usually known as phthisical, and most often tuberculous). Such diseases were shown by Dr. Buchanan to be much less fatal in certain English towns, after they had been sewered and the soil consequently drained, than they had been previous to the construction of the sewer works. Where the drying of the subsoil was considerable, the deaths from phthisis were reduced by a third, or even by half, of what they had previously been.

Professor Pettenkofer and other Continental observers have sought to establish a relation between the height of the ground water and epidemic outbreaks of typhoid fever. Pettenkofer's observations were made on the wells of Munich; and they tend to show that when the water in these wells was at its lowest level, especially after a rapid fall succeeding an unusually high level, outbreaks of the fever occurred. Munich is built on a porous sandy soil, at that time riddled with cesspools, of which the contents rapidly soaked into the surrounding soil; so that it is conceivable that after heavy rainfall liquid cesspool filth should find its way into the wells, and the outbreak of typhoid fever two or three weeks after the specific pollution of the drinking water might be coincident with a fall in the ground water to its usually low level.

In this country no invariable relation has been found to exist between the onset of typhoid fever epidemics and low level of ground water.

In considering this subject, it must not be forgotten

that there are other factors, such as temperature, condition of the soil as regards moisture and freedom from pollution, etc., which may have a more direct bearing on health conditions than the level of the ground water. The right view appears to be that fluctuations of level are of but little consequence in themselves, but that by favouring pollution of water in wells, and by forcing impure ground air into houses, they exercise a most considerable influence on health.

Pettenkofer has expressed similar views with regard to cholera outbreaks ; but it cannot be said at present that the facts, on which these views are founded, warrant more than a recognition of the occasional occurrence of coincidence of cholera outbreaks with a low state of the ground water. Epidemic diarrhœa occurring in summer and autumn has also been shown to be dependent on certain soil conditions (*vide* p. 224), and the infection of yellow fever is also generally held to have some relation with the soil.

The connection between malaria and damp marshy soils capable of holding stagnant water—the breeding-grounds of the mosquito (*Anopheles*)—is more firmly established. In many instances, malarious districts have been rendered healthy by subsoil drainage or by tree-planting. In hot climates, trees and vegetation abstract large quantities of water from the soil, which is evaporated from their green leaves. It has been calculated that an oak-tree evaporates eight and a half times the rainfall over the area it covers, whilst the *Eucalyptus globulus* absorbs and evaporates eleven times this amount. The latter shrub has been extensively planted in many malarious districts, and has had considerable effect in rendering them more healthy. The soil has been dried by permanently lowering the level of

the subsoil water; and the moisture factor being withdrawn, the malarial agents (mosquitoes) are no longer provided with an environment favourable to their propagation. It must be remembered also that moisture favours decomposition of putrefiable material; therefore a dry soil is cleaner, and the ground air is purer than in a damp one.

In very malarious districts it is advisable that houses should be raised above the ground on arches open to the air, or in the case of wooden houses on piles. Moist ground around the site of the house should be drained and filled in, and the surface paved or covered with grass kept closely cut. Jungle and excessive vegetation should be cleared away and burnt.

From the above remarks it will be seen that, in the choice of a site for a house, a dry, fairly open and sunny situation, and a pure, dry, and porous soil should be chosen—if possible, in an elevated position and on a gentle slope favouring natural drainage both on the surface and in the subsoil. Valleys lying in the direction of the prevalent winds are more healthy than those lying in other directions. In cold and temperate climates, sands and gravels, if of considerable depth, and not waterlogged by reason of a low situation and an underlying stratum of clay, are the healthiest, because the warmest (most absorbent of heat) and the driest. Gravel patches have sometimes a clayey or loamy matrix, and may thus be themselves retentive of water. Clayey soils are cold, because little absorbent of heat, and they are also damp from the retention of moisture, and therefore not so healthy as the more permeable soils. The disadvantages of living on clay are materially reduced by elevation with good surface falls. Chalk is usually dry, but, being little absorbent of heat, is cold. In hot

climates sands are excessively hot, unless covered with herbage, which protects from the sun's rays, and cools the air by evaporation of moisture. Trees also check evaporation from the ground, and thus favour dampness. They may be utilized, at a sufficient distance from the house, for sheltering from the north and east winds.

In towns, *made soils*—which are often mere excavations made for the purpose of removing the virgin gravel, and subsequently filled in with all sorts of rubbish and dust-bin refuse—should be avoided. If the soil is damp, the entire site below the foundations should be drained by laying unglazed agricultural pipes in trenches filled in above with pebbly gravel. This allows free percolation of water into the pipes, through the porous material of which they are constructed, and between their ends, which are laid in apposition, but not jointed. The sub-soil drains should not be connected with any soil drain, sewer, or cesspool, but should discharge, if possible, into a ditch or stream. In open soils, such as sands, a single drain will lower the level of the ground water over a considerable area, whereas in stiff close soils numerous drains are necessary.

To prevent the entrance of ground air, the entire site of the house, within the external walls, should be covered with a layer of cement concrete, 6 inches thick, rammed solid; and the surface thus formed should be grouted over with cement. In large town houses with basement floors below the street level, the cemented surface when asphalted or paved may conveniently form the finished flooring; being free from cracks and crevices, it can afford no lodgment for cockroaches or other vermin, which so frequently infest the lower storeys.

In houses without cellars, more especially where the site is not concreted over, the lower floors should be

raised 2 feet above the surface of the ground, and the intervening space should be well ventilated through air-bricks in the external walls.

Great care must be taken that the excavations for the house foundations are protected from the access of water; otherwise they serve to store moisture and occasion serious dampness in the basement. The building should be erected on a uniform bed—not partly on gravel and partly on clay, for instance, as there would then be unequal resistance to the superincumbent pressure. If the building is on sloping ground, it should be well protected from moisture on the side towards which the surface waters flow. A chalk foundation should be first well tested, as cavities or pipes therein may lead to subsidence. Clay slopes are undesirable sites, because the clay may shrink and crack after a prolonged drought, or swell and soften after much rain, and thus injure the foundations.

A wall built of ordinary building bricks and mortar is very porous, and capable of absorbing large quantities of water. Each brick can hold about 16 ounces of water.

To obviate damp from the ground rising in the walls, a horizontal damp-proof course of slates bedded in cement, a half-inch layer of asphalt, or slabs of perforated glazed stoneware, should be inserted in the wall slightly above the level of the ground adjoining (Fig. 31). The stoneware slabs answer a double purpose; they are not only damp-proof, but the perforations afford an air passage through the wall, and ventilate the space under the flooring—a very necessary precaution to prevent dry rot in timbers and joists.

Damp-proof courses may even be inserted in the walls of old buildings, by removing a course of bricks piecemeal, and then inserting air-bricks in sections.

The external house walls, when these pass below the surface of the ground, must be separated from the ground by an "open" area extending upwards from the footings or foundation. Where space will not admit of an open area, a "dry" area should be formed (Fig. 31).

This is merely an area a few inches wide, carried up well above the surface of the ground, to prevent the moist earth coming in contact with the wall, and is

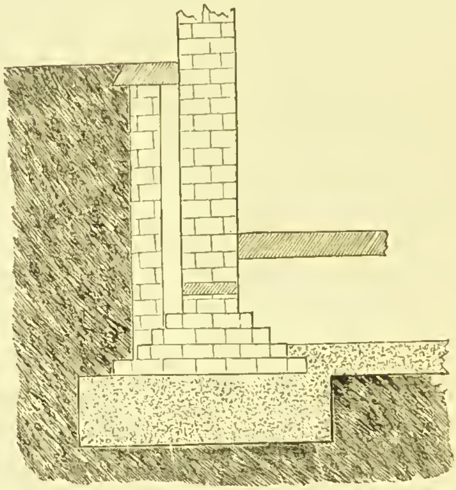


FIG. 31.—HOUSE FOUNDATION WITH DAMP-PROOF COURSE IN WALL AND DRY AREA.

covered at the top; or a double wall may be formed below the ground level so as to enclose a vertical air space; this arrangement necessitating two damp-proof courses—the lower just above the footings, and the upper across the outer portion of the double wall above the ground level. These provisions are necessary to prevent damp cellars and basements.

In very exposed situations the outer walls of houses are liable to become damp from driving rain. The usual remedies are the covering of the walls with slates or glazed tiles, or coating the brickwork with Portland

cement, which, being impervious to moisture, is found to answer extremely well.

House walls constructed of soft porous bricks jointed with bad mortar are especially liable to become damp from soaking in of rain. If both bricks and mortar are soft and rotten, the wall should be coated with cement; if the bricks are sound, but the mortar decayed, the wall should be repointed with good cement.

Sometimes in new houses the wall-papers are stained from temporary dampness, which is due to the evaporation of the water in the bricks and mortar ("building water").

Another common cause of damp walls is defective gutters to the roof, or broken or otherwise damaged rain water pipes. In both these cases water drips down the walls, and, soaking through the bricks and mortar, causes a permanent dampness and moisture in the rooms within. A further source of damp in the walls of basements or ground-floor rooms is the absence of proper paving of the ground around the house, where damp-proof courses or open areas do not exist, as is the case in most artisans' and labourers' dwellings in large towns. The rain, or the water from a leaky tap, soaks into the ground around the house unless it is paved and sloped to a drain inlet, and in time saturates the brickwork. In most towns the local authorities now compel house-owners to pave the yards and areas around working-class dwellings. The best material for yard paving is cement concrete, the Portland cement being first well dried and then thoroughly mixed with clean sharp sand. Asphalt also makes a good paving. Other materials used are blue glazed Staffordshire bricks and York flagstones, but in these cases a good hard and smooth bottom of concrete should first be laid.

Generally the natural surface soil of a locality is too thin to materially affect the sanitary conditions of a site, but it may occasionally reach a depth of several feet.

Low-lying alluvial tracts are not desirable sites for residences, for the ground water is either very near the surface, or the ground is water-logged for many months of the year; and the site is damp, subject to fogs, and affords an unreliable foundation for buildings. When an alluvial site is on the borders of a river, it is liable to flooding, and it becomes extremely difficult to secure dry basements. There is, moreover, great difficulty in providing efficient drainage for the sewage of the house, especially where the houses have basements.

An intimate relation exists between the sanitary condition of streets in urban districts and the prevalence of summer diarrhœa. The sanitary condition of streets depends not merely upon the use made of them, but also upon the materials of which they are constructed, and the manner in which they are kept, as regards the frequent removal of slop and dust.

A perfectly good road should have a firm dry foundation, with a hard, tough, and compact surface, the latter being neither too flat to allow water to stand, nor too convex to inconvenience traffic.

The substitution of mechanical power for horse traction would be a great sanitary advancement, and in the matter of street-cleansing would effect a great saving of expense. The usual method of bringing trade refuse out into the streets, and the general littering which results, is a practice which ought not to be allowed. In large urban communities a considerable proportion of the population spend the major part of the day in the streets, and their houses practically abut upon them. The necessity, therefore, of keeping the streets as wholesome as possible by

guarding them from all avoidable animal and vegetable pollution by frequent scavenging is obvious, and makes itself specially felt in the hot weather, when the odours given off from badly scavenged streets are most marked, and the suspended dust (of horse-dung, etc.) is highly unpleasant and irritating to the eyes and throat. The desirability, from a public health standpoint, of perfectly sanitary roads is being increasingly recognised year by year. Frequent flushing by hand-cart or by hose has possibly some effect in reducing summer diarrhœa prevalence.

The chief kinds of road-paving are macadam, granite setts, wood, and asphalt. Regarded from the sanitary aspect, macadam creates by far the most mud and dirt, and is therefore expensive to maintain and cleanse; it is noisy and very absorbent. Constant watering in dry weather, and cleansing of the surface at all times, are absolutely necessary to maintain a macadam road in good condition.

Granite setts furnish a most enduring pavement, easily and cheaply repaired and cleansed, and practically non-absorbent. The great objection to this form of pavement is the noise arising from the wheels of the vehicles and the iron shoes of the horses striking upon it. The noise can be diminished by running the joints with asphaltic composition instead of the ordinary Portland cement grouting.

Wood paving is the most expensive, but possesses the following advantages:—It is almost noiseless; it is clean, and creates no mud of itself until it is worn; cleansing is comparatively easy, when not much worn; and, though slippery at times, a fall does not hurt a horse like a fall on a macadam road. The disadvantage is its capacity for absorption, with the giving off of offensive

odours during the hot dry season; but this is in some measure obviated by the use of hard woods creosoted under pressure, and jointed with impervious material.

Asphalt is the most sanitary paving, being smooth, impermeable, jointless, and most durable. It is cleansed, swept, and flushed more easily than any other kind of paving, and is admirably adapted for all classes of town roads and streets which are level, or have only very slight gradients. Its chief disadvantage is that it is slippery when first damped with rain, and that horses fall very heavily on it. It is doubtful, however, if it is more slippery than wood under similar circumstances. For motor traffic and for pedestrians asphalt forms an ideal paving material.

The Sanitary Construction of the House.

General Considerations.—With regard to aspect in this country, north and north-eastern aspects are cold, whilst southern are warm; north-western and south-western are exposed to boisterous winds, and in the latter also to driving rains; the south-easterly aspect is generally dry and mild, and is well selected for the living-rooms of a house. Sunshine should be capable of entering every living-room at some time of the day. The provision of bay-windows will help to secure this desideratum. The sufficient lighting of every room is most important. Gwilt's rule that there should be 1 square foot of glass to every 100 cubic feet of room-space is probably rather an under-estimate of the requirement in towns; on the other hand, excessive window provision makes a room very warm in summer and cold in winter.

All staircases, passages, or corridors should be well lighted and ventilated direct from the outside air.

Bedrooms should have, where practicable, an east or south-east aspect, so as to get the morning sun ; they should have plenty of window area and an open fire-place.

Too little attention is often given to the situation of the larder, and it is frequently found in a most undesirable position—badly lighted, badly ventilated, the window opening just above the dust-bin, and one (stucco) wall separating it from a water-closet. The larder should face north for coolness, and have provision for a through current of fresh air ; the window or windows should be protected with perforated zinc to exclude insects.

All chimneys should be kept as much as possible together, and protected from cold so as to favour upward draught.

The most sanitary wall coverings for water-closets, bath-rooms, and sculleries are glazed tiles, or the walls may be covered with a silicate paint ; in either case they can be easily and frequently cleansed. For bedrooms distempering is to be preferred to wall-paper. If in the sitting-rooms wall-paper is employed, one with a smooth varnished surface should be chosen in preference to an uncleanly, absorbent flock-paper.

As to the floors, the ordinary floor boarding supported on floor joists, placed 1 foot apart, and leaving an open space some inches in depth between the floor surface and the concrete foundation or the ceiling of the room below, has little to recommend it. The space beneath the floor becomes a receptacle for dirt, which gets through the cracks between the floor boards. Whenever such a floor is laid down it should be made with grooved and tongued, or ploughed and tongued boarding, so as to insure the boards being tight-fitting. But it is far preferable that "solid floors" should be constructed by laying the floor

joists side by side and nailing the floor boarding to the solid upper surface of the joists.

Glazed tiles and bricks form satisfactory floors for water-closets, lavatories, bath-rooms, sculleries, and larders. The best floor covering for the rest of the house is hard wood, such as oak well fitted, beeswaxed, and polished; or hard, well-seasoned deal, stained and well varnished. Parquet flooring insures a uniform and impervious surface. For roofing, some non-absorbent material is to be preferred. Roofs of thatch and wood are liable to be damp and to harbour insects, and their inflammability is a source of danger. Slates and tiles are good materials; the former are light, but, being good conductors of heat, are cold in winter and hot in summer, whereas the latter, though heavy, are warmer in winter and cooler in summer. Lead, zinc, and copper have all been used for roofing; like slates, they are good conductors of heat, and impervious.

In house-furnishing, woolly and fluffy articles of decoration, heavy draperies, fittings, and ornaments, which will harbour dust and render it difficult of removal, should be avoided; and carpets should not be made to cover the whole floor and be nailed to it, but should be laid down as squares which admit of easy removal for cleansing purposes.

Walls are generally built of brick, stone, timber, or concrete.

The materials used in building should be as compact and as impermeable as possible; all bricks should be hard and as little absorbent of moisture as practicable, all wood well seasoned, and the plaster impermeable.

CHAPTER VI.

CLIMATE AND METEOROLOGY.

Climate.

The human body possesses marvellous powers of adaptability to the varying external conditions occasioned by changes of climate and season, and the transition from cold to heat, dryness to humidity, and *vice versâ*. The normal temperature of the body is sustained, and the bodily functions are properly performed, under all the varying conditions of climate and season to be met with in the habitable globe.

In hot climates, where the temperature of the air approaches, or even exceeds at times, the temperature of the blood, there is little call made upon the heat-producing powers of the body. Consequently metabolism is decreased; the urea of the urine and the respiratory carbonic acid are lessened in amount, as less food is required; the digestive and assimilative powers are lessened; and oxygenation of the blood is diminished, because the number of respirations is decreased, and the heated air contains less oxygen in a cubic foot than cold air. At the same time great heat, although compatible with health, is enervating; for the perfection of bodily activity can only be obtained when tissue changes are rapid. In hot climates the skin is extremely active, and the

secretion of sweat enormously increased. This means great evaporation from the surface and cooling of the blood, with the result that the body temperature is maintained at its normal level.

The effects of cold are exactly the reverse to those of heat. To maintain the temperature of the body, tissue metamorphosis must be rapid ; food, and especially carbonaceous food, must be taken in large quantities ; oxygenation of the blood and elimination of CO_2 are increased ; the skin functions are reduced to a minimum, while the excretion of urine increases, and but little blood reaching the surface, surface cooling is obviated ; whilst the rapid tissue changes permit of great bodily and mental activity being shown.

Great humidity of the air causes lessened evaporation from the lungs and skin. For the air, being saturated, or nearly so, with moisture, has little drying power, and the moisture from the skin and lungs is with difficulty evaporated. The evaporation of moisture, by which much heat is rendered latent, is one of the chief sources of cooling of the body. Consequently, when the air is hot and very moist, the humidity tends to increase the effects of the heat ; the blood is with difficulty kept at its proper temperature ; and all the disagreeable results of the high temperature are intensified. Moreover, the humidity of the air affects the climate of a place by hindering the terrestrial radiation of heat.

When the air is very dry, and especially when it is also warm, so that its capacity for taking up moisture is very great, the evaporation from the skin and the lungs is increased. In chronic lung diseases, such as bronchitis, emphysema, and some cases of phthisis with much congestion or bronchitis, dryness of the atmosphere causes cough and irritation, no doubt from the increased evapora-

tion thrown on the lungs. The warm, equable, and fairly moist climates are best suited for the treatment of these complaints.

For healthy people in temperate climates, the pleasantest degree of humidity is about 75 per cent. of saturation (relative humidity 75).

The effect of movement of air (winds) on evaporation is very great. In cold weather a chilly wind, if dry, increases the evaporation, and also lowers the temperature of the body by the impact of its cold particles, which absorb the heat of the body, and then pass away to be replaced by more cold air. The skin becomes dry and chapped, and the lungs are irritated. In hot climates a dry, hot wind increases the evaporation enormously.

The warm and moist south-west winds in the British Isles are mild and relaxing, while the dry and colder east and north winds are bracing.

At high altitudes the air is rarefied, and the pressure of the atmosphere is diminished. The other conditions met with in mountain climates, as contrasted with those of plains, are: (1) Greater movement of air—strong winds are very prevalent; (2) lessened humidity; (3) increased sunlight; (4) great freedom of the air from suspended matter—mineral and organic (bacteria, fungi, and spores); (5) a larger amount of ozone in the air; (6) a lowered temperature generally; but as the soil is rapidly heated by the sun, the days in summer may be warm, whilst the rapid radiation of heat, as soon as the sun sets, causes sudden cooling and a very low temperature at night. Temperature decreases with altitude to the extent of about 1° F. to every 300 feet of ascent.*

* The weight of oxygen in a cubic foot of air is diminished in proportion to the diminution of pressure; thus, if the barometer stands at 20 inches, the 130·4 grains of oxygen present in a cubic foot of

Although the weight of oxygen in a cubic foot of air is decreased at high altitudes, the oxygenation of the blood is increased, for the respirations are more frequent and have greater depth ; and after a short period of residence the capacity of the chest is found to be increased in all its measurements, together with increased power of expansion and contraction. The action of the heart is also increased, and tissue change is stimulated by the low temperature and the dryness of the air, leading to improved digestion, assimilation, and excretion, with increased bodily activity.

These effects of residence at a high altitude, together with the freedom of the air from dust and germs, and its impregnation with ozone, have led to the treatment of cases of phthisis at mountain resorts, with often the most beneficial results. The cases most benefited are those in an early stage without much congestion or bronchitis, which might be aggravated by the cold dry air. It is advisable that spots should be chosen which are sheltered from cold winds ; and those popular resorts, where many phthisical persons are crowded together in hotels and boarding-houses without proper precautions being taken, should be avoided. As much time as possible should be spent in the open air.

A mountainous district in proximity to the sea is liable to excessive rainfall. The moist currents of air blowing in from the sea are chilled by striking against the mountain chain ; clouds are formed, and some of the moisture, no longer able to be held as invisible vapour, on account of the lower temperature, is deposited as rain, snow, or sleet, according to the temperature and season

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dry air at 30 inches of mercury and 32° F., is reduced to $\frac{20}{30}$ of 130·4 = 86·9 grains only.

of the year. If the mountains are in the centre of a continent far removed from the sea, the rainfall may not be great. The excess of moisture in the ocean currents will already have been deposited before reaching the hills ; and in these situations a mountain climate, without the drawback of excessive rainfall, may be obtained suitable for the requirements of consumptives and invalids. The westerly winds which blow over the Rocky Mountains deposit most of their moisture on the western sides of the range, and on the eastern slopes the climate is comparatively dry and cold.

Increased pressure of the atmosphere produces effects very much of an opposite nature to those just considered. It is found, however, that the system quickly accustoms itself to increased atmospheric pressure, and that men can work vigorously in diving-bells, in the compressed-air chambers necessary to lay the foundations of bridges and aqueducts under water, and in the very deepest mines.

The painful effects of exposure to high atmospheric pressure are generally referred to as "caisson disease." A caisson is a cylinder of iron plates riveted together, which is sunk on the bed of a river so as to form a shaft. Into this, when closed at the top, air is pumped under sufficient pressure to force the water out of the lower part of the shaft, and to keep it out while men excavate the bed of the river, for the purpose of obtaining a suitable foundation for the piers of bridges. There is at the top part of the cylinder, near to the closing diaphragm, a chamber or "air-lock," in which the pressure of the air can be gradually increased or diminished. By this means the men, before entering the compressed air in the shaft, are subjected to a pressure, which is gradually increased, until it equals that within the shaft. Similarly, on

leaving the shaft the men are gradually "decompressed" in this lock before emerging into the outside air.

The workers are liable to suffer from the altered conditions of atmospheric pressure to which they are daily subjected, and they are affected far more by the consequences of decompression and returning to the outside air, than from compression and continuance of exposure to the high pressure in the caisson.

The leading symptoms of caisson disease are: (1) Unpleasant sensations or severe pains in the ears, doubtless the result of the tympanum being driven in by the compressed air. The drum of the ear is said to have been even ruptured, and sometimes deafness results. These ear symptoms are materially aggravated if the person happens to be suffering from a cold in the head or sore throat, when pain in the forehead is often marked. (2) Neuralgic pains. (3) A feeling of giddiness, with a tendency to fall. (4) Loss of power in the legs, amounting at times to paralysis. (5) Slight to severe pains in legs, arms, and shoulders. (6) Epistaxis. (7) Itching of skin. (8) Hæmoptysis. (9) Epigastric pain, and sometimes nausea and vomiting. (10) Occasionally unconsciousness. There is, of course, a physiological rise in the blood-pressure.

Three theories have been adduced to explain compressed-air illness. It has been held to be due to CO_2 poisoning; to the mechanical congestion of internal organs; and to increased solution by the blood of the gases in the compressed air, and the liberation of these gases during decompression. The last theory is most generally accepted. If the first were correct, the illness should occur while the men are in the caisson, and not after they emerge from it. In support of the second theory, it may be said that in several necropsies the

membranes of the brain, etc., have been found deeply congested.

The symptoms mostly benefit from recompression, followed by slow decompression lasting some forty-five minutes.

The favouring causes are: Too long stay in the compressed air, insufficient ventilation of the compressed-air space—the amount of illness varies inversely with the extent of the provision for ventilation (Snell), too rapid decompression, fulness of habit, advancing age, over-indulgence in alcohol, and organic disease. New hands suffer more than the old.

The preventive measures to be adopted include: Working during short shifts—if the pressure exceeds 35 pounds, the shifts should probably not exceed four hours, and if the pressure reaches 50 pounds, two hours; the abundant supply of fresh air; electric lighting to be employed, so as to insure the continued purity of the air; the rate of decompression certainly not to exceed one minute to every 3 pounds of pressure; the systematic examination of all hands, and the selection of those most fitted; advice to be given as to how to inflate the middle ear by swallowing air when uneasiness first appears, as to the importance of rest for a short period after leaving the compressed air, and as to the necessity for extreme temperance with alcohol.

The climate of small islands and of places on the sea-shore differs from that in the interior of continents chiefly in its greater equability. The variations in temperature between day and night and between summer and winter are much less marked, whilst the winds blowing in from the sea bring a moist but pure air, rich in ozone and free from dust and germs. The specific heat of water is far greater than that of the solid rocks composing the earth's

crust ; hence water heats slowly, but parts with its heat slowly. The land heats quickly and radiates quickly, but on the land it is the surface alone which is affected by the change of seasons. At Greenwich the variations between summer and winter temperatures at a depth of 25 feet are only about 2° F. In winter the ocean acts as a storehouse for the heat absorbed from the summer sun, and slowly parts with it to warm the superincumbent air. In summer the land is heated by the sun more rapidly than the water ; consequently, the air over the land is heated and rises, and a cool breeze blows in from the sea during the day. During the night the earth is rapidly cooled by radiation, if the sky is clear ; the air over the sea is then warmer than the air over the land, it rises, and a land breeze sets out to sea. On a summer's day at the seashore the air is constantly in motion, and is cool and moist, whilst in the interior it may be insufferably hot, close, and dry. Marshes, by the evaporation from the shallow water, help to lower the summer temperature ; but the influence of large lakes, as in North America, is to bring about an almost insular climate in summer, and a continental one in winter, for the frozen lakes then exert a similar influence to land.

Ocean climates are of the greatest benefit to certain cases of lung disease (bronchitis, emphysema, congestive phthisis), where a pure air, free from dust, but moist and of equable temperature, is desired. Ocean voyages should be recommended with extreme caution to phthisical patients. The confinement and overcrowding in cabins and state-rooms, the want of exercise, and the costive habit thus produced, tending to excite hæmoptysis, are all grave disadvantages, and may counteract any benefit to be derived from the sea-air.

The effect of vegetation on climate must not be lost

sight of. In cold climates trees and shrubs obstruct the passage of the sun's rays to the soil, which is therefore liable to be cold and moist; but in hot climates the evaporation of water from the leaves tends to dry the soil, whilst the temperature of the air is lowered, and the ground is sheltered from the direct rays of the sun and kept cool. Thus, the heat of summer is lowered and the cold of winter lessened by the presence of trees, and, having a lower temperature than the neighbouring earth's surface, high forests increase the rainfall. In very dense forests the air is generally stagnant, and if there is much moist and decaying vegetation all the conditions productive of malaria may be present in a high degree. Probably in all climates a due admixture of herbage, shrubs, and trees, without dense undergrowth, but admitting the passage of free currents of air in every direction, is the most conducive to health. Large tracts of country destitute of trees and vegetation are in hot climates unbearably warm and dry, and in cold climates are exposed to every chilling wind and to every extreme of temperature, according to the season of the year. In such districts, too, rainfall is often absent or very slight in amount, the attractive influence exerted by trees and vegetation generally upon water-charged clouds being wanting. For these reasons the Desert of Sahara gives to the South of Europe a much higher temperature than would otherwise be the case.

Thus, the mean temperature of the air of any place is dependent on the latitude, the altitude, the relative proportions of land and water, the aspect, and the nature of the soil; and the extent of the diurnal variations in temperature is largely determined by the proximity to the coast and the height above sea-level. The "amplitude of the yearly fluctuations" in temperature is

not more than about 4° F. in some tropical places at sea-level, while it may be as much as 110° F., or even more, in the heart of large continents situated near the poles.

The principal factors, therefore, which determine the climate of a district are : (1) Distance from the equator; (2) distance from the sea; (3) altitude; and (4) prevailing winds.

Of the many separate elements that go to make up the climate of a place, temperature is the most important, and the mean annual temperature depends primarily upon the amount of radiant heat received from the sun. The heat received from the sun, however, in one place may be carried by winds and ocean currents to another. The mean temperature of the tropics is about 80° F., and that of the arctic circle in latitude 60° is 25° F., the difference of some 55° F. being due to the fact that the heat received from the sun is concentrated upon a small surface when the sun's rays fall near the equator, and is spread over a large surface when they fall near the poles. The difference would be far greater were it not for the heat carried away from the tropics to the temperate and arctic regions by ocean currents, and to a less extent by winds.

The difference between summer and winter temperatures is also important, but little variation being shown in places within the tropics, or on islands in the middle of large oceans, either in tropical or temperate latitudes.

The heating of the air in the tropics, the cooling around the poles, and the deflective action of the earth's rotation, produce all the prevailing winds of the globe. The colder air of the northern and southern regions of the globe is constantly flowing towards the warmer and more rarefied air over the open seas on both sides of the equator. The result of the earth's rotation on the flow of the warm water from the equator towards the poles in

the North Atlantic Ocean is the large circular swirl, the northern and eastern sides of which produce the well-known current of the Gulf Stream. This current, together with the circumstance that the prevailing winds have a westerly direction, accounts for the British Isles possessing such a mild climate; whilst countries with the same latitude as England—such as Labrador and Eastern Asia, in which the prevailing winds are from the land instead of from the sea—have a mean winter temperature below zero.

Weather Observations.

Under the modern system, a number of barometrical readings taken at the same time over an extended area, such as the greater part of Western Europe, are telegraphed to a central station, where they are laid down upon a map. On this map lines are drawn connecting the places showing equal barometrical pressure; these lines are termed "isobars." This weather-map will show the cyclonic or anticyclonic systems, as the case may be, their position, and their extent. A cyclonic system is a system having at its centre the lowest barometrical pressure, and surrounded by isobars of gradually increasing pressure. The isobars will be near or far apart according to the amount of depression in the centre. If this depression is great, then the isobars are generally close together, and the gradients are said to be steep. If, on the other hand, the depression in the centre is shallow, the isobars are further apart, and the gradients are shallow.

An anticyclonic system is the reverse of this, for its centre is the highest barometrical reading, and it is surrounded by isobars of gradually decreasing pressure.

In order to restore atmospheric equilibrium, the air

tends to move from a region where the barometer is high and pressure greatest, towards one where it is low and the pressure is least. Consequently, currents of air set in from all sides towards the centre of a cyclonic system, and flow out in all directions from the centre of an anticyclonic system. These currents of air do not, however, as a matter of fact, flow straight to or from the centre, but have a gyratory movement imparted to them, owing to the rotation of the earth on its own axis.

The equatorial circumference of the earth being 24,900 miles, and the earth rotating on its axis once in twenty-four hours, it follows that a point on the earth's crust at the equator must be carried round at the rate of 1,040 miles an hour. In latitude 30°, however, the point would only move at the rate of 900 miles an hour, owing to the lesser circumference of the earth at this distance from the equator. In latitude 60°, the rate will be only 520 miles an hour, and at the poles it will be nil. Now, the atmosphere is carried round at the same rate as the earth's crust; consequently winds or currents of air travelling from the equator towards the poles, or from low latitudes into high, tend to keep the higher rate of rotatory motion imparted to them when nearer the equator, and become westerly—that is, appear to come out of the south-west (in the northern hemisphere) as they progress towards high latitudes. In the same way, winds travelling from high latitudes to low ones meet an atmosphere which is rotating at a greater rate than they are, and consequently appear to come out of the north-east (in the northern hemisphere). This is the reason why the trade winds which blow towards the equator are north-east winds in the northern hemisphere, and south-east winds in the southern hemisphere.

The same forces apply to the currents of air moving

towards the centre of a cyclonic system, or away from the centre of an anticyclonic system. In the case of a cyclonic system (in the northern hemisphere), a current setting towards its centre from the north is deflected to the west, or appears to come from north-east. A current setting towards the centre from the south of the system is deflected to the east, or appears to come from south-west. In this way a gyratory or spiral movement is imparted, which causes the wind to travel round the centre of a cyclonic depression, in a direction *against* the hands of a watch ; or supposing a person to be travelling with the wind with his face towards the direction the wind is taking, he will always keep the centre of the system, *i.e.*, the point of lowest barometer, on his left-hand side.

The central space of the cyclone is thus occupied by a vast ascending current, which after rising to a considerable height flows away as upper currents into surrounding regions.

The direction of the wind round an anticyclonic centre is exactly the reverse. The air flows away from the centre of greatest pressure in all directions. The current flowing southwards is deflected to the west, and appears to come from north-east. The current flowing northward is deflected to the east, and appears to come from south-west. Consequently the currents revolve *with* watch-hands, and the person travelling with the wind keeps the centre of the system—the point of highest pressure—always on his right hand.

From this it follows that having a weather (synoptic) chart before us, and knowing the distribution of pressure over the area included in the chart, we can generally tell the direction of the wind at any particular spot ; and if we know what course the system is taking, *i.e.*, the

direction in which it is travelling, we can predict what changes will subsequently take place in the direction of the wind at that spot, until it is no longer included in the system.

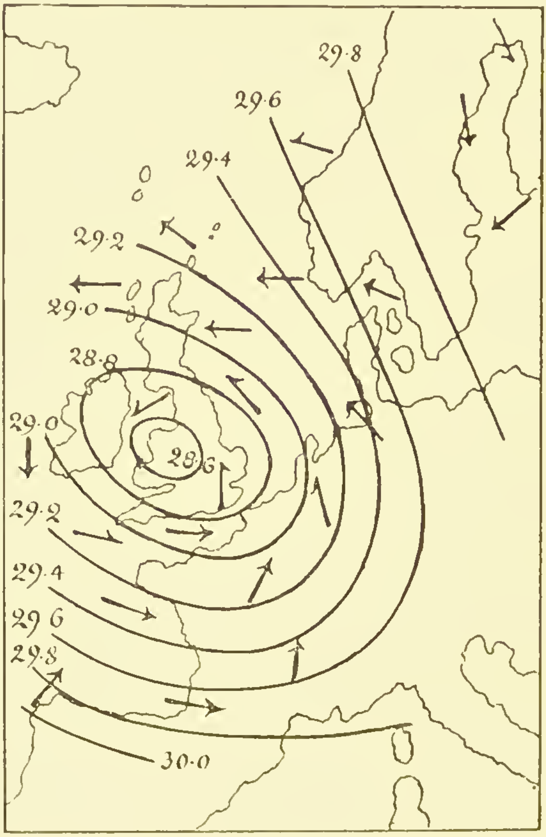

FIG. 32.—SYNOPTIC CHART SHOWING CYCLONIC SYSTEM.
The arrows show the direction of the wind. The figures show the barometric pressure of the isobars.

Cyclonic systems are never stationary. They move over the earth's surface, usually from west to east in European latitudes; and in the case of the British Isles, coming from off the Atlantic, their approach is difficult

to forecast. In these depressions the isobars lie close together and the winds are strong. As a rule, the greater the depression in the centre and the steeper the gradient, the more violent is the wind ; but, according to

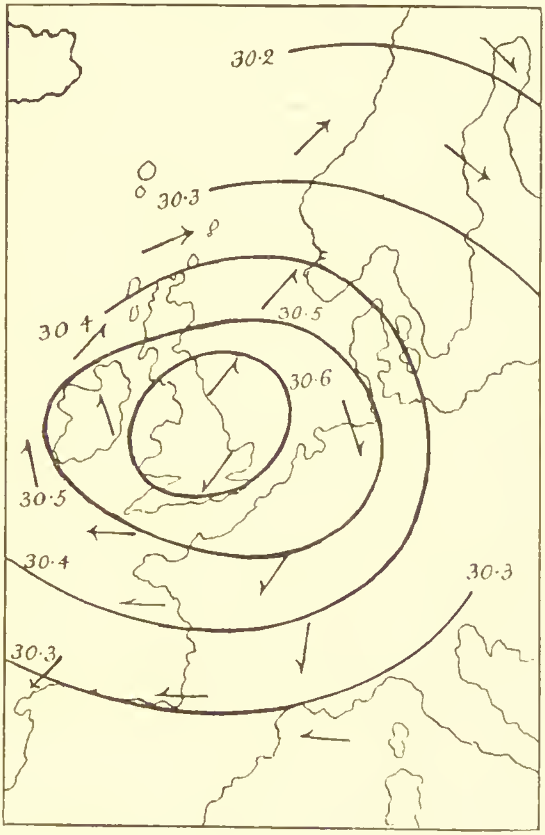

FIG. 33.—SYNOPTIC CHART SHOWING ANTICYCLONIC SYSTEM.

Scott, no simple relation between the force of the wind and the steepness of the gradient has yet been determined. In this country the arrival of cyclonic systems off our coasts heralds the approach of cloudy skies, wind, rain, and damp air. These conditions imply warmth in winter, and cold weather in summer. The centre of the cyclonic

depression usually lies to the north of the British Isles; consequently, these islands lying in the track of the southern portion of the system, the wind is first experienced from the south-east, it then shifts through south to south-west, and blows harder the more rapidly the mercury drops. When the barometer has reached its lowest point the wind flies round to west or west-north-west; the barometer then begins to rise, the rain ceases, the temperature falls, and as the wind becomes north the sky clears, and fine weather is again experienced (Scott).

Anticyclones, on the contrary, are generally more or less stationary, or move very slowly. The isobars lie far apart, and the winds are light. They are accompanied by fine weather, a dry atmosphere, a sky generally clear of clouds, though fogs are very likely to prevail at places. These conditions produce cold, frost, or fog in winter, and heat in summer.

The synoptic charts (Figs. 32, 33) show that the wind in both cyclonic and anticyclonic systems has a direction more or less parallel to the isobars, but still, on the whole, tending to cross the isobars very obliquely, so as to blow spirally towards the centre of a cyclone, and spirally away from the centre of an anticyclone.

Meteorological Instruments.

The Barometer.—The pressure of the atmosphere is expressed by means of a barometer in terms of the perpendicular height of a column of mercury, glycerine, or water, which it is capable of supporting. The weight of the atmosphere at the sea-level supports a column of mercury of 29·992 inches, or 760 millimetres, in height, a column of glycerine about 324 inches, and one of water 34 feet, in height. The water barometer is accordingly the most sensitive, but it is inconvenient in use.

The simplest form of mercurial barometer is a graduated U-tube, with one end closed. The closed arm is about 32 inches in height, and the open arm about 8 or 9 inches. The mercury placed in the U-tube is made to completely occupy the closed arm, so that all the air is displaced from it; then, when the tube is brought to its proper upright position, and the mercury falls, there is a complete vacuum left above it in the closed arm. The varying pressure of the atmosphere on the surface of the mercury exposed in the open (short) arm causes the level of the mercury to rise and fall in the long (closed) arm; and the difference between the levels in the two arms represents the height of the column of mercury supported by the atmosphere.

In a standard mercurial barometer, a vertical tube 33 inches long rises from a cistern of mercury, the tube above the level of the mercury being in a state of perfect vacuum. In Fortin's standard instrument (Fig. 34) the small cistern has a leathern bottom, which can be acted upon by a thumb-screw (*a*), enabling it to be tightened or relaxed so as to raise or lower the level of the mercury in the cistern. The scale for reading the height of the column of mercury is divided into inches, tenths, and half-tenths ($\frac{1}{20}$) of inches; and to obtain more accurate readings than the scale alone allows, a sliding scale or vernier (*b*) is attached, which serves to indicate the amount of space occupied by the mercury above the nearest half-tenth line. The vernier scale is divided into twenty-five equal parts, which correspond to twenty-four half-tenth divisions on the barometer scale. Consequently each division on the vernier is $\frac{1}{25}$th less than a half-tenth division on the barometer scale, and is therefore $\frac{1}{25}$ of $\frac{1}{20}$ of an inch ($= \frac{1}{500}$ or 0·002 inch).

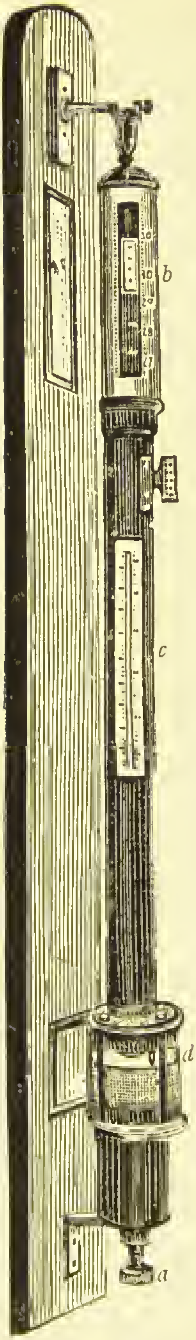

FIG. 34.—FORTIN'S STANDARD BAROMETER.

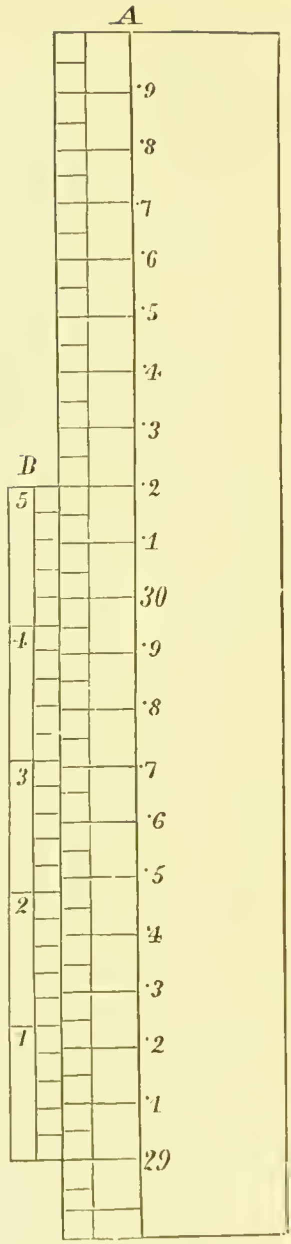

FIG. 35.—DIAGRAM OF BAROMETER SCALE AND VERNIER.

A, Scale; *B*, vernier.

In order to take an accurate observation, the eye, the zero edge of the vernier, and the top of the mercury, should all be in the same horizontal plane; hence the necessity of fixing the barometer at a height convenient to the observer. The temperature of the attached thermometer (*c*) is first noted; then the level of the mercury in the cistern is so adjusted that the ivory point (*d*) projecting downward from the roof of the cistern just touches the surface of the mercury. This little ivory point indicates the zero of the scale; and since the level of the mercurial surface in the cistern varies with every change of atmospheric pressure, the level of the mercury must be adjusted, prior to each observation, to the zero of the scale. Next read off on the barometer scale the division immediately below the top of the column of mercury. Then adjust the vernier (Fig. 35) so that its lowest line is level with the top of the column of mercury, and the light is just excluded between the lower end of the vernier and the top of the mercury, and count the number of divisions on the vernier from below upwards, until a line on the vernier exactly corresponds with one on the barometer scale. Multiply the number of the divisions on the vernier so obtained by 0·002, and add the result to the already observed height on the barometer scale. Corrections, by Glaisher's tables, must then be made for temperature above 32° F.—for mercury, like all other metals, expands with a rise of temperature. The mercury falls about $\frac{1}{1000}$ inch for every foot ascent above sea-level, and allowance must be made for this if the observation is made at an altitude.

The barometer must always be carefully and truly fixed by means of a plumb-line, in a good light and protected from sunshine, rain, and winds. Before fixing,

it should always be ascertained if the vacuum above the mercury is true. To do this, unscrew the bottom of the cistern until the mercury is 2 or 3 inches from the top, and then rather suddenly incline the instrument. If the vacuum is true, the mercury strikes against the top of the tube with a sharp click, but a dull sound results if air is present. In the latter case, screw up the bottom tightly, turn the instrument upside down, and tap the side forcibly until a bubble of air is seen to pass through the mercury column into the cistern. Barometric observations are always expressed to the third place of decimals; and isobarometric lines, as shown on charts, indicate areas over which the barometric pressures are identical. If the isobars, which are drawn for each $\frac{1}{10}$ of an inch, are close together, the "barometric gradient" is said to be steep, and the wind velocity will be high. In this country the diurnal range of the barometer seldom exceeds 0·02 of an inch.

The *aneroid barometer* is a small watch-shaped metal box from which the air has been exhausted, and in which the two flat surfaces of the box are kept apart by a powerful but sensitive spring. The atmospheric pressure acts upon the spring, and is recorded on a dial. This instrument is chiefly used for taking altitudes. The practice is to read the aneroid to the nearest $\frac{1}{100}$ of an inch, both at the commencement and at the termination of an ascent, and then to subtract one reading from the other (ignoring decimal points), and multiply the difference by 9, this giving the height of the ascent in feet.

Example.—

Reading at start = 30·00 inches.
Reading at end = 29·00 ,,

100
9

900 feet ascended.

The weight of a cubic foot of dry air at 32° F. and 30 inches of mercury is 566·85 grains. As air expands $\frac{1}{491}$ of its volume for every degree rise Fahrenheit, the volume at 60° F., for instance, is $1 + \frac{1}{491} \times (60 - 32) = 1 \cdot 057$ cubic feet. The weight is inversely as volume; consequently if x is the weight of a cubic foot of dry air at 60° F., $\frac{x}{566 \cdot 85} = \frac{1}{1 \cdot 057}$; or $x = \frac{566 \cdot 85}{1 \cdot 057} = 536 \cdot 28$ grains.

The weight of a cubic foot of water vapour at 60° F. is 5·77 grains. Therefore, the added weights of a cubic foot of dry air at 60° and of a cubic foot of vapour at 60° are 536·28 + 5·77 = 542·05 grains. But dry air expands on taking up moisture, and the actual weight of a cubic foot of saturated air at 60° is 532·84 grains, or 3·44 grains less than the weight of an equal volume of dry air, because the cubic foot of originally dry air now occupies more than a cubic foot. This fact explains the fall of the barometer when the moisture in the air is increasing and a fall of rain is imminent. The weight of a cubic foot of air is proportional to the height of the barometer. The percentage of nitrogen to oxygen in the air is by volume nearly 79 to 21, but by weight it is 77 to 23.

Robinson's Wind Anemometer is an instrument which records the velocity of the wind. The figure (36) sufficiently explains the construction of the instrument. The revolving cups set in action a train of clockwork, and the velocity of the wind is recorded on a series of dials. The cups travel at a rate equal to only one-third that of the wind, and allowance is made for this fact in graduating the instrument. The square of the velocity in miles per hour, multiplied by 0·005, gives the wind-pressure in pounds per square foot; and, on the other

hand, the square root of 200 times the wind's pressure gives the velocity.

The instrument must be kept clean and well oiled, and should be fixed at least 20 feet from the ground, and away from buildings. The average velocity of the wind is from six to eight miles per hour.

On the Beaufort scale, in a light wind, the air travels

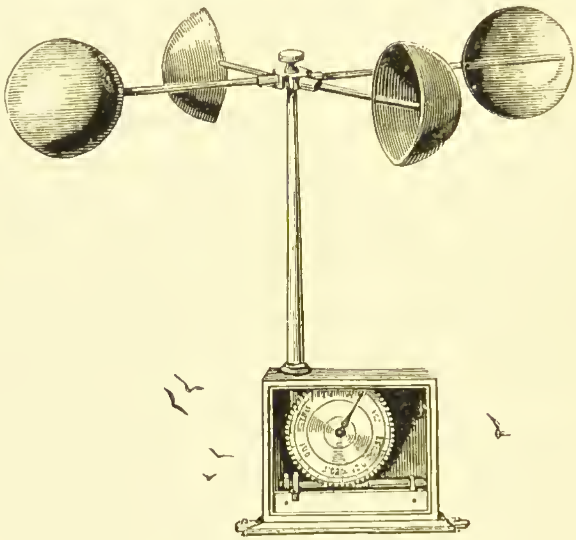

FIG. 36.—ROBINSON'S ANEMOMETER.

at a rate of 13 miles per hour; in a moderate breeze, 23; in a strong breeze, 34; and in a gale, 65.

All wind direction observations by vanes, etc., should be recorded to the nearest point of the compass.

The instruments which register the moisture in the atmosphere are known as *hygrometers*. Of these there are two distinct classes, *i.e.*, those which indicate the dew-point directly, and those from which the dew-point is indirectly ascertained.

In the former class the air is cooled until the moisture is deposited on a bright surface to which a thermometer

is attached, the latter indicating the temperature of the dew-point.

In Daniels' hygrometer (Fig. 37) ether is placed in the lower bulb, and the other bulb (which contains nothing but ether vapour) is covered with muslin moistened with ether. This ether on the muslin evaporates into the air, and the loss of heat so occasioned condenses the ether vapour inside the bulb, causing evaporation from the ether inside the other (lower) bulb. The lower bulb thus becomes gradually colder, and chills the air surrounding it, until a temperature is reached at which the air is compelled to part with some of its moisture, which condenses upon the bright metal band surrounding the bulb. Directly this takes place the temperature of the dew-point is read off from the attached thermometer. The temperature at which the dew disappears is next observed, and the mean between these two temperatures is taken as the dewpoint. In Regnault's instrument (Fig. 38) one cylinder is half filled with ether, and the other is left empty, thermometers being inserted in both cylinders. An aspirator communicates, by means of the hollow upright, with both cylinders, and when this is put in action air is drawn through them. The passage of the air through the evaporating ether soon cools it down to the dew-point, and then the bright metal surface surrounding the lower part of the cylinder becomes dulled with moisture. The temperature recorded at that instant by the thermometer in the ether is the temperature of the dew-point, the second thermometer simply showing

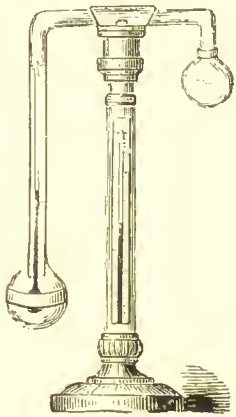

FIG. 37.—DANIEL'S HYGROMETER.

the temperature of the air at the time of observation. In Dine's instrument, a vessel which holds ice-water has a bright metal plate with an attached thermometer in its roof. As the cold water is made to flow under the plate, the outside air in contact with it becomes chilled ; and when the dew-point, as shown by the deposition of dew,

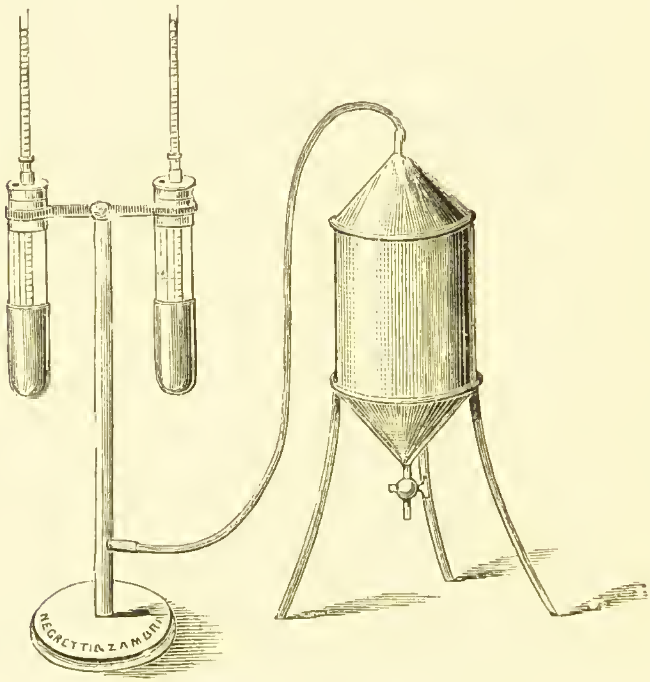

FIG. 38.—REGNAULT'S HYGROMETER.

is reached, it can be read off from the attached thermometer.

Wet and Dry Bulb Hygrometer.—This instrument consists of two absolutely identical thermometers mounted on a stand. In the wet-bulb thermometer the bulb is kept moist by being covered with muslin, one end of which dips into a small vessel of distilled or rain water, so that moisture ascends by capillary attraction. The

evaporation of moisture from the wet bulb, which takes place so long as the surrounding air is not saturated, causes loss of heat, and the wet bulb reads lower than the dry bulb. Both the vessel containing water and the wet bulb must be sufficiently far from the dry bulb to insure that the readings of the latter are not affected by the evaporation. The instrument must be exposed in the shade and protected from air currents and direct sunshine, both of which, by increasing evaporation, would cause the wet bulb thermometer to indicate a temperature not strictly due to the hygrometric state of the atmosphere. If the muslin becomes frozen in the winter, the two thermometers will read the same; then the wet bulb should be brushed over with cold water, and the evaporation which will go on from the frozen surface will enable a proper reading to be taken.

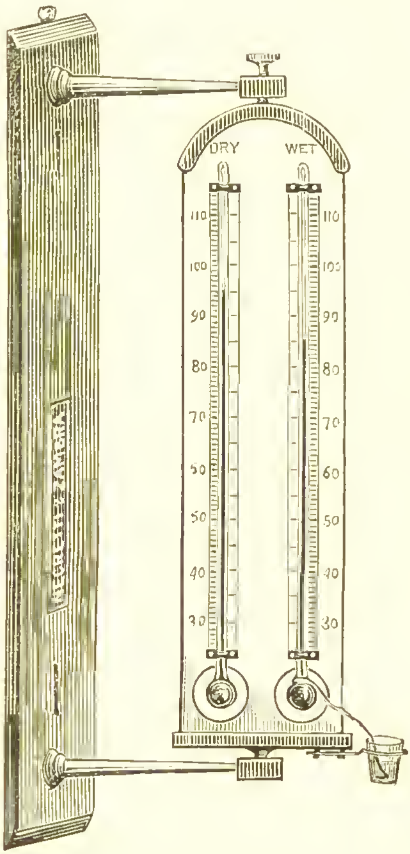

FIG. 39.—WET AND DRY BULB HYGROMETER.

From the readings of the dry and wet bulbs can be ascertained — the *relative humidity* of the air, *i.e.*, the amount of moisture present in air, expressed as a percentage of the amount just necessary to cause saturation ;

the *dew-point, i.e.*, the temperature at which the amount of moisture actually present in the air would cause saturation; and the *weight of vapour in a cubic foot of air*, from which can be deduced the additional weight of vapour necessary to cause saturation, or the *drying power of the air.*

The relative humidity is found from tables. The greater the difference between the dry and wet bulbs, the lower is the relative humidity. If the dry and wet bulbs record the same temperature, the air is completely saturated with moisture.

The dew-point can be determined by the equation: dew-point $= T_d - F\,(T_d - T_w)$; where T_d is the dry-bulb temperature, T_w the wet-bulb temperature, and F the factor opposite the dry bulb temperature found in Glaisher's tables.

In De Saussure's instrument (*the hair hygrometer*), a hair, freed from fat by ether, is fixed at one end, and this hair contracts with lesser and expands with higher degrees of humidity. The hair is kept stretched by a small weight, the connecting cord of which is led round a pulley; and an index needle attached to the pulley indicates the relative humidity on an empirically graduated scale of relative humidities. The instrument is standardized by first wetting the hair and noting whether it accurately registers saturation on the scale (*i.e.*, 100); but it is necessary to frequently verify the readings by other methods.

The "elastic force of vapour," or "the tension of aqueous vapour," is the amount of the barometric pressure which is due to the vapour of water in the atmosphere. If the temperature of the air is lowered, and with it the tension of aqueous vapour, a temperature will sooner or later be reached at which the air is saturated with

moisture; and then the slightest further reduction in temperature will cause a deposition of dew ("dew-point"). The tension of aqueous vapour is ascertained from tables or by formula. The relative humidity can be calculated by dividing the elastic force of aqueous vapour at the temperature of the dew-point by the elastic force of the aqueous vapour at the temperature of the air, and then multiplying by 100.

Example.—The dry-bulb temperature is 62° F., and that of the wet bulb is 56° F. The dew point is therefore

$$62 - \{(62 - 56) \times 1{\cdot}86\} = 50{\cdot}84° \text{ F.}$$

The aqueous tension at 62° F. is (from Glaisher's tables) 0·556 of an inch of mercury, and that at 50·84° F. is 0·372 of an inch. The relative humidity is, therefore, $\frac{0{\cdot}372}{0{\cdot}556} \times 100 = 66{\cdot}9$ per cent. of saturation.

Atmometers, for determining the amount and rate of evaporation, have been devised. In these instruments a known volume and weight of water is exposed in a receptacle, so as to present a known surface area to the atmosphere; and the evaporation in a given time is determined by the loss either in volume or in weight of the original water.

The weight of moisture which a cubic foot of dry air can take up, before it is saturated, varies with the temperature. The higher the temperature, the larger is the amount of vapour required, as the following table shows:

GRAINS OF VAPOUR TO SATURATE A CUBIC FOOT OF DRY AIR (APPROXIMATE).

30° F.	2 grains	66° F.	7 grains	80° F.	11 grains
41° F.	3 ,,	70° F.	8 ,,	83° F.	12 ,,
49° F.	4 ,,	74° F.	9 ,,	86° F.	13 ,,
56° F.	5 ,,	77° F.	10 ,,	88° F.	14 ,,
61° F.	6 ,,				

If the relative humidity at 61° F. is 70, the amount of vapour in a cubic foot is 70 per cent. of saturation, or $\frac{7}{10}$ of 6 = 4·2 grains; and the drying power of a cubic foot of the air is 6 -- 4·2 = 1·8 grains.

Rain Gauge.—This instrument consists of a vessel supporting at its top a circular funnel which collects the rainfall. The instrument must be sunk in level ground, away from shrubs and buildings, to such a depth that the collecting surface is one foot from the ground. A measuring glass, graduated according to the area of the funnel, so as to indicate the fall of rain as decimals of an inch, is required. The area of the top of the circular funnel (the receiving surface for the rain) is usually 50 square inches. To graduate the measuring glass for a funnel of this area, 50 cubic inches of water are poured into it, and a mark placed at the level the fluid stands at. The glass below is then divided into 100 equal parts, so that each division indicates a fall of 0·01 inch of rain. The readings are generally taken daily at 9 a.m.

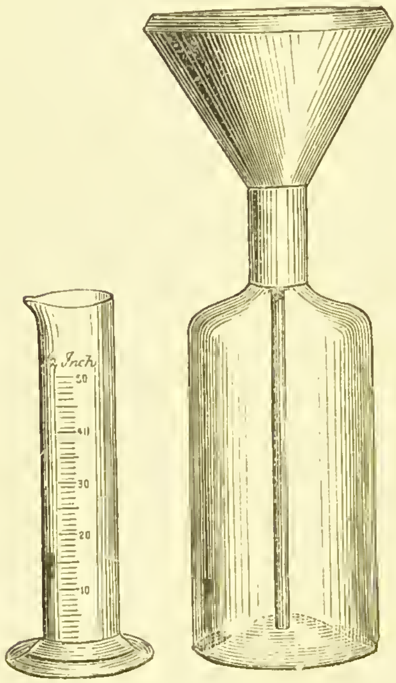

Fig. 40.—Rain Gauge.

In time of snow, melt the collected snow by adding a measured quantity of warm water to it, and express the extra water derived from the snow as rain water.

The average depth of the adjacent snow should also be noted.

In Crosley's self-registering rain-gauge every $\frac{1}{100}$ of an inch of rainfall is recorded on a dial. The rainfall collected gradually fills one compartment of a small bucket divided into two compartments, and balanced on a pivot. When one compartment is full, the bucket tips and causes an index to record, and the second compartment then commences to fill.

At 32° F. 1 cubic foot of dry air can only hold 2·13 grains of moisture, whereas at 100° F. 19·84 grains can be taken up. Hence, when warmer air, already moisture-laden, is chilled, the moisture representing the difference between what it originally held and what it is capable of holding at the reduced temperature is deposited in the form of dew or rain.

Aqueous vapour requires free surfaces for its condensation. When air is filtered, no cloud of condensed vapour can be formed. "Wet fogs" result when the particles of suspended matter are relatively few and the condensed moisture excessive, whereas "dry fogs" occur when the smoke and dust are relatively abundant. When the films of moisture are discoloured by the products of coal combustion, a yellow or "pea-soup" fog will result.

The death-rate generally increases as a result of town fogs, and the increase is ascribed to the irritating effects of the impurities in the atmosphere, causing bronchitis, etc., and to the sudden fall of temperature which takes place on the occurrence of the fog. Fogs lead to a considerable loss of that important element, sunshine, in our great towns: for, as a rule, when the town is enveloped in fog there is a cloudless sky above.

Clouds consist of collections of condensed aqueous vapour. The principal forms which they assume are:

(1) The cirrus, consisting of separate fine feathery formations, generally white in colour; (2) the stratus, consisting of a smooth horizontal stratum of cloud; (3) the nimbus, constituting the raining clouds, of dark-coloured, irregular forms; and (4) the cumulus, or heavy, thick, well-defined clouds, generally rounded off in shape. Two or more of these four principal forms may be mixed together, giving rise to appearances which are defined as "cirro-stratus," "cirro-cumulus," "strato-cumulus," "cumulo-nimbus," etc.

Thermometers measure the temperature by the amounts of expansion and contraction of certain bodies when these are exposed to varying degrees of heat and cold. Mercury is commonly employed, because of its very low freezing-point ($-38°$ F.) and its high boiling-point ($675°$ F.); but alcohol is preferred where very low temperatures may have to be recorded, because it does not freeze at the greatest known degree of cold.

The instruments are graduated from the fixed points of freezing and boiling water, by plunging them into melting ice and boiling water, respectively, at the standard pressure. On the Centigrade scale the freezing and boiling points are $0°$ and $100°$ respectively, while on the Fahrenheit scale the freezing-point is $32°$ and the boiling-point $212°$; therefore, to convert Centigrade to Fahrenheit, multiply the former figure by $\frac{9}{5}$ and add 32, while to convert Fahrenheit to Centigrade subtract 32 and then multiply by $\frac{5}{9}$.

Maximum thermometers are instruments designed to register the highest temperature reached during the period of exposure of the instrument; in these the temperature is registered by mercury. The registration is effected by either breaking the column of mercury by an air-bubble, or by a slight narrowing of the tube near the

bulb. In either case the natural cohesion of the metal when contracting is overcome, and the mercury always remains at the highest point reached. Another method is to insert a small piece of solid glass enamel in the bend near the bulb; this, acting as a valve, allows the mercury to pass on one side of it as it expands, but does not allow it to return on cooling. In hanging a maximum thermometer, it is necessary to see that the end of the tube furthest from the bulb is slightly inclined downwards, to assist in preventing the return of any portion of the column of mercury into the bulb on a decrease of temperature. Before reading the instrument, the end furthest from the bulb should be gently elevated to an angle of about 45°.

Minimum thermometers record the lowest temperature reached. They are alcohol instruments, with an index in the alcohol (Rutherford's) which moves with the spirit on contraction by cold, owing to capillary attraction, but not on expansion, and is therefore left registering the lowest temperature. The end of the index furthest from the bulb indicates the minimum temperature. Occasionally air-bubbles appear in the alcohol and fix the index. They can be removed by holding the thermometer with the bulb downwards, and swinging it round rapidly at arm's length. These instruments should be hung so that the bulb end is 1 inch lower than the other end, because then the index is less likely to be affected by a rise in temperature.

The so-called "*earth*" *thermometer* is a maximum thermometer which is suspended by a chain in a stout iron tube, 5 feet long, which is provided with a pointed metal cap. By this means the temperature of the earth at depths up to nearly 5 feet can be ascertained. In taking an observation the thermometer must be quickly drawn up and read.

In *Six's thermometer* (Fig. 41) there is a U-tube, the middle part of which is occupied by mercury. The bulb (*a*) and both tubes above the mercury contain alcohol, in which are two steel indices, which are brought, by means of a magnet, to rest upon either column of mercury; and *b* is a small chamber containing air. On a rise of temperature, the alcohol, expanding in the bulb (*a*), depresses the mercury level in one arm, and therefore raises it in the other, the maximum temperature being indicated by the position reached by the lower end of the index. Conversely, as the temperature falls the alcohol in the bulb contracts, and the pressure of the air in the chamber *b* depresses the mercury level in the arm immediately beneath, and therefore raises the mercury level in the other arm, in which the index then registers the lowest temperature experienced. Thus, in the arm *c* maximum temperatures are registered, and in the arm *d* minimum temperatures.

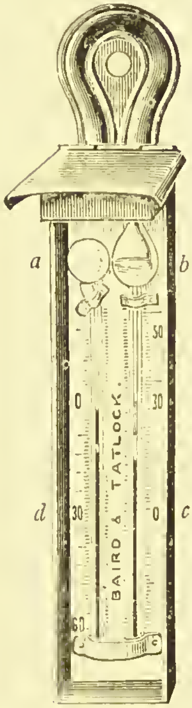

FIG. 41.—SIX'S THERMOMETER.

A *barograph* and a *thermograph* are instruments which furnish a record of the barometric pressure and of the temperature for the whole twenty-four hours of the day and night. The records are traced on slowly-revolving drums worked by clockwork. The instruments require repeated standardizing. In the recording aneroid barometer the fluctuations of atmospheric pressure act upon a series of aneroid vacuum chambers, a sensitive index attached to the latter recording the results. In one form of thermograph the record is continuously marked by an index

attached to a delicate metal spring, the expansion and contraction of which is dependent on the atmospheric temperature.

Isocheimenal lines are lines drawn through districts, as shown on a chart or map, having the same winter temperature; and isothermal lines similarly indicate districts with the same mean annual temperatures.

Shade maximum and minimum thermometers should be placed horizontally in the shade, or in a Stevenson's louvred box, 4 feet above the ground and at least 20 feet away from buildings or other sources of radiation.

The vacuum solar radiation thermometer (Fig. 42) is a mercurial maximum self-registering instrument, with a blackened bulb, which absorbs the sun's rays. It is placed in a glass case from which air is exhausted, thus protecting the bulb from loss of heat, which would ensue if the bulb were exposed, owing to atmospheric currents and the absorption of heat by aqueous and other vapours. This instrument is placed 4 feet above the ground, and is directly exposed to the sun's rays. The bulb should point south-east in this country. The difference between the maxima in the sun and in the shade is a measure of solar radiation, or of the power of the sun's rays.

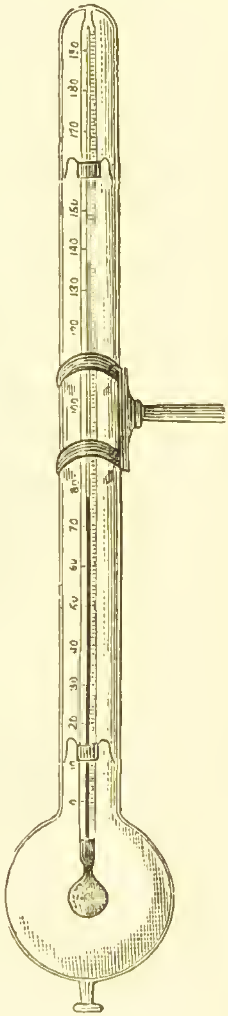

FIG. 42.—SOLAR RADIATION THERMOMETER.

Other instruments which may be found useful are:—A *terrestrial radiation thermometer*, which is merely a minimum

shade thermometer placed close to the ground, the bulb resting on grass—the difference between this minimum temperature and the air minimum in the shade being taken as the amount of terrestrial radiation; a *sunshine recorder* (Campbell-Stokes'—Fig. 43), a little instrument by which the rays of the sun are concentrated on to a strip of millboard stretched in a frame at the proper focal distance from a large spherical lens. When the sun shines, a charred line is burnt in the millboard, and when hidden

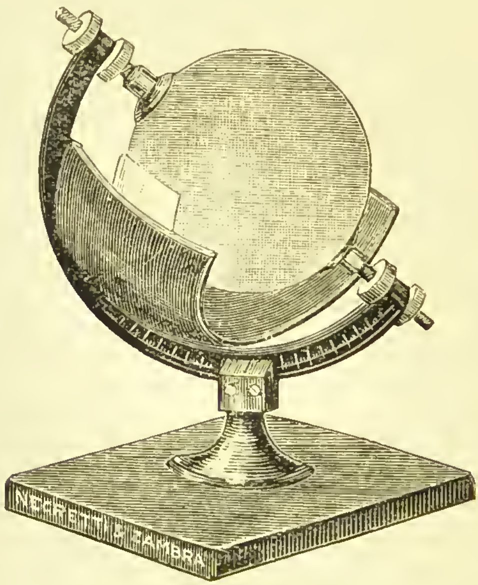

FIG. 43.—SUNSHINE RECORDER.

by clouds the record ceases. Results are best expressed as a percentage of the possible sunshine; *i.e.*, if the sun is above the horizon for ten hours, and the record is but one hour, the sunshine equals 10 per cent. of the possible amount.

Jordan's instrument is a sunlight rather than a sunshine recorder. By this instrument a straight line of sunlight is recorded on sensitive cyanotype paper placed

in two semicircular dark chambers. The sunlight, being admitted through small apertures in the sides, travels over the sensitive paper or chart by reason of the earth's rotation, and leaves behind a record of the duration of sunshine and the relative degrees of its intensity. The instrument must be carefully adjusted to the meridian and to the latitude of the place. To this end the base plate of the instrument must be inclined until the index points to the divisions on the arc corresponding to the latitude of the station; then turn the instrument until it faces due south, taking care that the base is perfectly level. When the sun is on the meridian, the sunshine passing through the apertures should fall on the chart line indicating twelve o'clock. One box takes the records for the forenoon, and the other for the afternoon, thus enabling the charts to be changed without interfering with a continuous record.

Atmospheric Electricity.

The atmosphere is charged with electricity, which is chiefly positive in fine weather and negative in wet. The sources of this electricity are:—(1) Vegetation, (2) evaporation from water containing salts in solution, (3) the unequal distribution of heat, leading to (4) atmospheric friction, and (5) combustion at the earth's surface (giving off positive electricity). Vegetation furnishes electricity by the evaporation of moisture, and by the giving off of CO_2 and O charged with positive electricity.

When clouds charged with different electricities (positive and negative) approach each other, a thunderstorm results. The heat generated along the track of an electric discharge causes the "lightning," and the thunder probably results from the sudden expansion of the air conse-

quent upon the lightning, and the subsequent inrush of air to restore the resulting partial vacuum.

Lightning-rods are generally of iron, of about 1 inch in diameter, and pointed with copper. They are carefully insulated, one end being buried in the ground. They must be fixed at a distance from any of the metal pipes of a building.

CHAPTER VII.

EXERCISE AND CLOTHING.

Exercise.

The effects of exercise on the body are as follows:

1. Increased force and frequency of the heart's action, and the increased circulation of the blood through all parts of the body. 2. The pulmonary circulation being quickened, more carbonic acid and water are taken to the lungs and eliminated. The amount of air inspired and expired is largely increased, and the oxygenation of the blood is consequently accelerated. 3. The action of the skin is heightened, and perspiration becomes marked, large quantities of sweat being poured out of the sweat glands. The evaporation of the sweat from the surface of the body regulates the temperature and prevents any rise above the normal. 4. The water and salt of the urine are decreased owing to the large cutaneous secretion, but the nitrogen (in the form of urea, uric acid, and extractives) is unaffected. In the period of rest following excessive exercise, the nitrogen elimination may be slightly increased. 5. The voluntary muscles are brought into active play; the circulation of the blood through them is accelerated; waste products are rapidly carried

away for excretion ; whilst the material for new tissue is brought to them.

It is thus seen that exercise, which means muscular action, involves more rapid combustion, as shown by the increased elimination of carbonic acid and water. Thirst and appetite are created, and water and carbonaceous foods are taken to supply the waste; whilst an increased amount of nitrogenous food, during or after periods of exercise, is necessary, first to enable the muscles to enlarge and harden, and secondly to replace the waste caused by the nitrogenous tissues performing their function of regulating oxidation.

Regular exercise in the open air is most essential to brain-workers, to purify the blood from waste matters, and to stimulate the action of the bowels.

After active exercise the body should be well washed with soap and water to remove the secretion from the sweat and sebaceous glands, which, if left on to dry, becomes mixed with shed epidermic scales from the scarf skin, and renders the skin not only dirty, but also damp, from the excess of common salt in the sweat, which absorbs moisture from the air. The damp skin causes surface cooling, and often gives rise to a dangerous internal chill.

If the exercise is too severe the heart is overstrained, breathlessness and palpitation are brought on, and the pulse becomes small, very frequent, and irregular. Prolonged exertion of a severe kind thus tends to cause cardiac pain and palpitation, and may give rise to hypertrophy of the left ventricle, if the overexertion is habitual. Rupture of bloodvessels from overexertion is uncommon before middle life. The muscles, including the cardiac muscle, require rest to get rid of the accumulated products of their action (possibly lactic acid), and

to take in a fresh store of oxygen. Without definite periods of rest suited to the kind of exercise, the muscles become exhausted, and their contractions are gradually enfeebled, until they cease altogether. The diastole of the heart is quite sufficient for its recuperation when the body is at rest.

The diet of men in training should differ little, if at all, from an ordinary diet. The amount of fat and nitrogenous food may be somewhat increased out of the usual proportion to the carbo-hydrates; but to deprive men of bread, potatoes, and vegetables, and to feed them on half-raw beef-steaks—as was formerly so largely done—is a ready means of causing the "staleness" so well known to trainers. Plenty of water, in small quantities at a time, should be allowed as the system demands. After a few days of training, excessive thirst and excessive sweating disappear, and the right balance between income and outcome of fluid is quickly struck. The capacity of the chest and the elasticity of the lungs and chest walls are notably increased by regulated training, especially by training for rowing.

From numerous observations it has been deduced that an ordinary day's physical work for a healthy man is equivalent to 300 tons raised 1 foot (foot-tons). This is an amount of work which can be sustained day after day without loss of weight and without inconvenience. Work represented by over 400 foot-tons daily cannot be kept up unless the diet is much increased, and even then there is likely to be loss of weight and muscular vigour. It has been shown that a man walking on a level surface at the rate of three miles per hour does work equivalent to raising his own weight plus the weight he carries a height equivalent to one-twentieth the distance walked. At quicker rates of speed this "coefficient of traction"

more nearly approaches unity ; thus, at four miles an hour it is between one-sixteenth and one-seventeenth, and at eight miles per hour the coefficient is barely one-tenth.

The following formula is useful for estimating the amount of work done by a man in walking :

Let W = weight of the man,
W′ = weight he carries,
D = distance walked in miles,
C = co-efficient of traction ($\frac{1}{20}$ at three miles an hour).

Then $\frac{(W + W') \times D \times 5{,}280}{20}$ = foot-pounds done in walking the distance D at three miles an hour. This number divided by 2,240 (the number of pounds in a ton) gives foot-tons ; or generally the formula may be expressed :

$$\frac{(W + W') \times D \times 5{,}280}{2{,}240} \times C = \text{foot-tons.}$$

About seventeen miles at three miles an hour, for a man weighing 150 pounds and carrying no weight, is an average day's work of 300 foot-tons.

Clothing.

The ordinary garments of civilized life are made either of one or a mixture of two or more of the following materials : Cotton and linen from the vegetable kingdom ; wool and silk from the animal kingdom.

Cotton materials have a smooth, fine texture, but not equal in these respects to linen. Under the microscope cotton is seen to consist of flattened fibres with well-marked twists in their course. There are no joints or nodes, and no branching fibres (Fig. 44).

Cotton garments are durable, and do not shrink in washing. They are non-absorbent, and rapidly conduct away heat ; hence cotton is the wrong material for under-garments, for it soaks up the perspiration and becomes wet, and the moisture is re-evaporated, causing a chill

to the surface of the body. The heat of the body is not retained by cotton, but is rapidly dissipated. A novel material called "cellular" cotton cloth obviates the last defect. In this material the fibres are so woven as to form

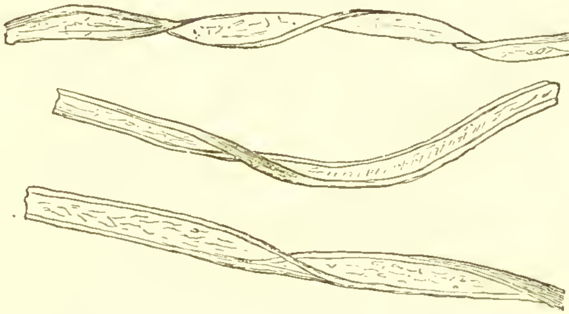

FIG. 44.—COTTON FIBRES. (× about 200.)

FIG. 45.—LINEN FIBRES. (× about 200.)

cellular air interspaces in the texture. Air being a bad conductor of heat, the cellular cloth is much warmer than ordinary cotton clothing. Cotton materials are preferable to woollen for the outer clothing of sick and

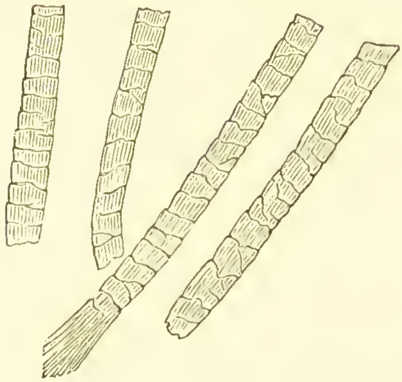

FIG. 46.—WOOL FIBRES. (× about 200.)

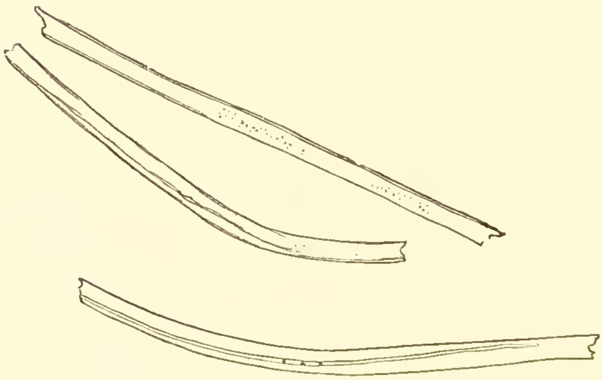

FIG. 47.—SILK FIBRES. (× about 200.)

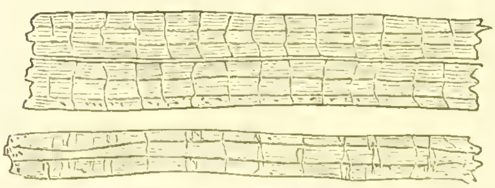

FIG. 48.—HEMP FIBRES. (× about 200.)

hospital nurses, as organic matters in the air cling far less easily to cotton than to wool, and they are more readily cleaned.

Linen materials have a very fine, smooth, and close texture. Under the microscope the fibres of linen are seen to be cylindrical and jointed, with minute branching filaments at intervals (Fig. 45). These latter are the elementary fibres of which the main fibre is composed. Linen is a good conductor of heat and a bad absorbent of moisture, like cotton, and is even an inferior material for underclothing.

Wool forms a valuable material for clothing. Under the microscope the fibres (Fig. 46) are seen to be rounded, colourless (unless dyed), with fine cross-markings, and reticulations in the border at the site of the cross-markings. There is a central longitudinal canal, but it is generally obliterated. The cross-markings and reticulations are best seen in new wool. When the fibres are old and worn, they are not so distinct.

Wool is an extremely bad conductor of heat, and is very absorbent of water and moisture, hence its value as a material for underclothing. Being a non-conductor, wool is warm by preventing the dissipation of the bodily heat. Its non-conducting properties are partly due to the wool fibres themselves, which contain an animal oil in their substance, and partly to the air entangled in their interspaces. After exercise causing perspiration, the moisture is absorbed and retained by the wool, and the vapour is condensed, thus giving back to the body the heat rendered latent by evaporation from the surface of the skin. A woollen garment after exercise is therefore warm and dry, and prevents the chilling of the surface from the lowering of the temperature by evaporation, which is so dangerous. In hot climates especially, wool should be worn next the skin to ward off those chills which are so often the forerunners of dysentery, diarrhœa, and ague.

The disadvantages of wool are the hardening and shrinkage the fibres undergo when frequently washed (especially where soda and strong soaps are used), and the loss of absorbency resulting therefrom. The wool fibres, being hygroscopic, readily absorb organic vapours and dirt from the body, so that woollen under-garments require frequent but careful washing. They should be washed in soft cold or tepid water, with mild soap without soda, and should not be much wrung out. Flannel, which is a woollen material, is also often found to be too irritating to be worn next to a delicate skin.

It has lately been discovered that the addition of a little kerosene or paraffin to the soap used for washing clothes facilitates the removal of dirt, as less rubbing and wringing of the clothes are then required; but the clothes must be well rinsed after the washing and aired out of doors, or a slight odour of kerosene (when kerosene soap is used) is retained in the fabrics. The paraffin soaps are free from this defect. The grease and dirt cannot be removed from clothes (any more than from the skin, owing to the fatty secretion from the sebaceous glands at the roots of the hair follicles) by merely washing in water without the use of soap. The alkali of the soap combines with the grease and emulsifies it, whereby it is easily washed off; whilst the fatty acid prevents the too great removal of the oil from the wool fibres, and the deterioration of the fabric. Cheap soaps, containing an excess of alkali, are bad for the skin, for it is rendered over-dry and loses suppleness by excessive removal of sebaceous secretion; and they are also injurious to woollen fabrics by carrying away the animal oil contained in the fibres.

In merino, wool and cotton are mixed in varying pro-

portions. "Shoddy" is old used and worked-up wool and cloth.

Silk (Fig. 47) is a bad conductor of heat, but is less absorbent than wool. It presents some advantages for underclothing, as it is more cleanly and shrinks less than wool, and is less irritating to the skin; but it cannot hold perspiration like wool. It is expensive, and is less durable than cotton or merino.

Leather and Waterproof Material.—These are invaluable for exposure to very cold bleak winds and rain. Leather is the more suitable for very cold climates. Being impermeable, they are extremely warm, but this impermeability prevents the ventilation and renewal of the layers of air confined under the clothing near the skin. The discomfort that arises from the wearing of waterproofs in warm weather is well known.

In hot climates the outer garments should be white or gray in colour to protect from the direct rays of the sun.

At the two extremes of life—in childhood and old age—warmth of covering is most essential. Children lose heat rapidly and are liable to chill, partly because, the circulation being rapid, more blood is carried in a given time to the superficial vessels, and more heat is thus radiated from the surface, than in an adult; but mainly because in children the surface of the body is larger in proportion to its bulk or contents than is the case in adults.

Children should be clothed in woollen materials, and the legs, arms, neck, and chest should be equally protected with the other parts of the body.

In old age the circulation is often feeble and languid, and the functions of heat production and regulation are less efficiently performed than before senile decay com-

menced. Consequently, if the body is chilled, the restoration to the normal heat is slow, and the vital functions are dangerously depressed.

Aniline dyes are now largely used for colouring various dress materials and under-garments, such as stockings. As a rule, the dyes used are free from arsenic; but it has occasionally happened that eczematous sores have been produced on the feet and legs by wearing dyed stockings, and there can be but little doubt that the sores were due to the action of arsenic on the skin when the feet were hot and damp.

A good material for clothing purposes must meet the following requirements:

1. It must afford proper protection to the body against cold and heat, so as to assist in preserving it at a proper uniform temperature in winter and summer alike.

2. It should interfere as little as possible with the natural functions of the skin.

3. It must exert no irritating or poisonous effects upon the skin.

Clothing is warm in proportion to its capacity for retaining the natural heat of the body, and therefore the materials which are the worst conductors are the warmest. Arranged in the order of their warmth, the materials in common use are: Wool, fur and down, silk, cotton, and linen. But the warmth of an article of clothing also depends upon certain other subsidiary circumstances. Thus, the *colour* of the most external clothing is important, black absorbing more of the heat from external sources than any other colour, and white the least of all. The order in which the different colours absorb heat is as follows: Black, dark blue, light blue, dark green, turkey red, light green, dark yellow, pale straw, and white. The degree of porosity of the article

also affects its warmth, for the small spaces are occupied by air, which is a bad conductor of heat; flannel is the most porous article of clothing, and silk is the least porous. Again, the textile fabrics with rough surfaces are generally warmer than those which are smooth, the rougher surfaces stimulating the skin and favouring the capillary circulation. The hygroscopic properties of the material determine its warmth to a considerable degree, for this property of absorbing moisture enables the fabric to absorb the perspiration from the skin ; and the chilling effect of the evaporation of this natural moisture is thereby transferred from the skin to the article covering it. The following is the order in which the various articles of clothing must be placed, so as to indicate their relative hygroscopic properties : Wool, fur, eider-down, silk, linen, cotton. The same order will indicate the facility with which each material absorbs odours.

A few general remarks may next be made upon the requirements of suitable and healthy clothing. The clothing of the body should be designed for the following purposes : (1) For preserving the whole of the body at a uniform temperature. Doubtless the dress of women and children offends chiefly against this requirement. Women's dress encourages a very unequal distribution of warmth ; the upper part of the chest and the legs are unduly exposed, whereas the trunk below the upper part of the chest is, by comparison, clothed very warmly. The dangerous habit of exposing the bare legs and arms of infants to the vicissitudes of our winter climate, and swaddling the rest of their bodies with many layers of warm clothing, should be obvious to all. (2) Clothing must interfere with no natural function or movement, so as to lead to injury of the part of the body to which it is applied.

The head-covering should be light, porous (so as to admit air), and with no tight rim to press upon the scalp and interfere with the circulation of its blood-supply, which is a frequent cause of baldness. No tight-fitting article should be worn round the neck, as important vessels are specially liable to be pressed upon in that situation. The trunk and extremities have probably suffered most from the adoption of bad principles in clothing; and the dress of women in many respects still defeats the main objects of clothing. Petticoats and dresses are often heavy; they impede movement and accumulate dirt, and they exert a dragging weight from the waist and hips. They should either be, like the male trousers, suspended by braces, or hung from a bodice by means of buttons.

The effects of tight lacing are to deform the body and to displace important viscera. The diaphragm is pushed up, the lung space diminished, and the lungs and heart often suffer in consequence. The constriction and displacement of the liver, and the resulting pressure on other important abdominal organs, causes them to suffer also. Those who lace tightly are frequently, therefore, the victims of dyspepsia, malnutrition, gastralgia, vomiting, shortness of breath, palpitation, and faintness. Tight, rigid corsets give rise to muscular flabbiness, which conduces to spinal curvature, round shoulders, and a stooping carriage. The waist of the average woman should be from 26 to 27 inches in circumference.

Tight sleeves should also be avoided. Suspenders should always be preferred to garters; and the lower extremities of women should be protected by thicker stockings in the winter. The substitution of warm "bloomers" for the petticoat is a practice to be commended.

With reference to boots, these should fit the foot, and

at the same time admit of free movement. Tight or badly-fitting boots may give rise to flat-foot, ingrowing toe-nails, corns, bunions, and even to permanent lameness. The soles should be flexible and the heels kept low. High heels cause the foot to press forward in the boot, tiring the walker and causing a feeling of discomfort. They also give rise to an uncertain and unbecoming gait.

In conclusion, it may be said that clothing should not be changed according to calendar, but according to weather; that the best material for underwear is light and porous flannel; and that clothing worn in successive layers is warmer than when a similar weight of material is applied in a single layer.

CHAPTER VIII.

FOOD, BEVERAGES, AND CONDIMENTS.

FOOD.

THE purposes fulfilled by food may be defined to be as follows:

1. To form new tissues in the process of growth.

2. To repair and renew the wasted tissues—solid and fluid—of the body.

3. To provide the material which serves as fuel to the body, and which, by its combination with oxygen, is reduced to the simpler forms of urea, carbonic acid, and water, thus supplying the sources of the animal heat and of the manifestations of energy which are essential for the maintenance of life.

All the various food substances and proximate constituents of food may be classified broadly under two heads—as nitrogenous and non-nitrogenous.

The albuminates, which are substances allied in chemical constitution to albumin, form a large proportion of the nitrogenous food substances; whilst the non-nitrogenous substances consist of the fats, the carbo-hydrates, the vegetable acids, the mineral salts, and water.

Nitrogenous.			Non-Nitrogenous.				
			Fats.	Carbo-hydrates.	Vege-table Acids.	Salts.	Water.
Albuminates	Animal	Albumin	Olein	Starch	Oxalic	Sodium chloride	
		Fibrin	Stearin	Dextrine	Tartaric	Potassium chloride	
		Syntonin	Palmitin	Cane-sugar	Citric	Calcium phosphate	
		Myosin	Margarin	Grape-sugar	Malic	Magnesium phosphate	
		Globulin	Butyrin	Lactose or	Acetic	Iron, etc.	
		Casein		Milk-sugar	Lactic		
		Gelatine					
		Ossein					
		Chondrin					
		Keratine					
	Vegetable	Gluten					
		Legumen					
Extrac-tives		Kreatine					
		Kreatinine					
		Karnine					
		Xanthine					

Albuminates or Proteids.—The average composition of albumin may be taken as being somewhat as follows: In 100 parts—nitrogen 16, carbon 54, oxygen 22, hydrogen 7, sulphur 1. The proportion of nitrogen to carbon is nearly in the ratio of 2 to 7. In the group headed by gelatine (see table) the N is about 18 per cent., and the proportion of nitrogen to carbon is greater: these substances are much less nutritious than the albuminates proper. In the process of digestion albuminates are converted into albumoses and soluble peptones, which are highly diffusible and capable of passing through the inner coats of the alimentary tract into the blood and lymph streams. A part of the peptones is further transformed into leucin and tyrosin, but the final products derived from proteid food are carbonic acid, water, and urea. Peptones differ from common albumins in being soluble, uncoagulable by heat, acid, or spirit, and in being dialysable.

Nitrogenous foods are essential for the maintenance of animal life. All organized structures contain nitrogen, and there can be no chemical change and no manifestation of energy in any animal tissue from which nitrogen is absent. Consequently, nitrogenous foods are required for the formation of new and the repair and renewal of old tissues, and for the formation of the digestive and other fluids of the body. The nitrogenous tissues of the body are also the regulators of the absorption and utilization of oxygen, by which energy is manifested; therefore the proteid foods, which make and repair the tissues, also participate in this regulation of oxidation and energy. They are also supposed to have another function under certain special conditions, viz., the formation of fat and the yielding of energy; but of this little is known, and doubtless the main source of energy is the oxidation of non-nitrogenous substances. Under a diet from which nitrogen is withheld the body languishes; the functions are carried on at the expense of the existing tissues and structures, and these undergoing no renewal, death must eventually result.

The albuminates proper are of nearly equal nutritive value, and are therefore mutually replaceable in a diet. This applies both to the different members forming the animal albuminate class and to the vegetable and animal albuminates taken as two separate classes. The only advantage—if, indeed, it be one at all—in favour of animal nitrogenous food as opposed to vegetable is that the former is more rapidly and completely digested, and therefore more quickly replaces wasted tissue. But against this must be set the fact, quite recently ascertained, that proteid substances are split up in the processes of healthy digestion, either in part or whole, into the poisonous alkaloids *ptomaïnes* and *leucomaïnes*. These bodies are, no doubt, under conditions of normal health

and activity, disposed of in the system without detriment to its vital functions ; but if they are produced in excess, or more rapidly than they can be destroyed or eliminated, as may happen after a meal of meat excessive in amount, they tend to accumulate in the system, and may be the cause of that heaviness and languor so frequently experienced by large meat-eaters, especially those of a dyspeptic habit.

Whilst there is not sufficient evidence to prove that vegetarianism, so-called, is more conducive to health or longevity than a mixed diet, there can be but little doubt that the wealthier classes eat too largely and too frequently of meat. Excess of nitrogenous food causes not only an abnormal production of the poisonous alkaloids, of whose potentialities for evil but little is at present known ; but an excess of nitrogenous waste accumulates in the blood, oxidation is interfered with, the liver, the kidneys, and the other excretory organs are overtaxed in their work of eliminating waste substances which are also insufficiently elaborated, and gout or liver and kidney disease result.

Gelatine, ossein, etc., are not the nutritive equals of the other albuminates, and cannot replace them. Gelatine is easily oxidized in the body, and appears to be of value in cases of acute disease, when given in the form of jellies, in preventing excessive tissue waste. In such cases the albuminates, if given, may not be digested or assimilated. Gelatine cannot, probably, form nitrogenous tissues, but it can take the place of part of the nitrogenous substances in the blood which undergo oxidation.

The extractives, such as those contained in the juice of flesh, appear to act as regulators and stimulants of digestion and assimilation, especially when gelatine and allied bodies are comprised in the diet. Hence the use of

beef-tea, which as usually made contains little beyond extractives, in the dietary of sickness.

Hydrocarbons or Fats.—These bodies are compounds of glycerine with the fatty acids—oleic, stearic, palmitic, etc. They contain no nitrogen, but are made up of carbon, hydrogen, and oxygen, the proportion of oxygen being less than sufficient to form water with the hydrogen present. The fats are unacted upon by the saliva and by the gastric juice, and pass through the stomach unchanged; but in the small intestine they are emulsified by the pancreatic juice and bile, and rendered capable of absorption by the lacteal vessels, whilst a small portion is saponified—*i.e.*, split up into glycerine and fatty acids, the latter uniting with alkalies to form alkaline palmitates, oleates, and stearates (soaps), which are directly absorbed into the blood or lacteals.

The chief function of the fatty foods is to repair and renew the fatty tissues, and to yield energy and keep up the animal heat by oxidation into carbonic acid and water. The presence of the fats in food promotes the flow of the pancreatic juice and bile; they thus help in the proper assimilation of other foods, and assist the excretory functions of the intestine, which are badly performed if bile and the other digestive fluids are not secreted in sufficient quantity.

The animal fats are more easily digested and absorbed than the vegetable. If there is excess of fat in a diet, it passes out unchanged in the fæces.

Carbo-hydrates.—These substances are made up of carbon, hydrogen, and oxygen, the oxygen being present in the exact proportion necessary to form water with the hydrogen present. In the process of digestion starch, cane-sugar, dextrine, and milk-sugar are converted into grape-sugar. This change is commenced in the mouth,

during the process of mastication of the food, by the action of the saliva ; it is not carried any further in the stomach, but is completed in the small intestine by means of the pancreatic juice. The starch ($C_6H_{10}O_5$) takes up a molecule of water to become grape-sugar ($C_6H_{12}O_6$), which is taken up by the blood and carried by the portal vein to the liver, where it is deposited as glycogen or liver starch. The liver acts as a storehouse for the deposition and accumulation of these converted starchy foods, which are subsequently supplied to the system as the needs of the economy demand, there to undergo oxidation for the manifestation of heat and energy, and to be used for the building up of the fatty tissues of the body.

The functions of the starchy foods are thus seen to be the production of animal heat and energy by oxidation, and the formation of new fatty tissues. The latter property has been demonstrated by Lawes and Gilbert by experiments in the fattening of pigs. The fat given in the food was not sufficient to account for all the fat stored up in the pigs. Most of it must have been derived from the conversion of the carbo-hydrates, but a portion may have been due to the metabolism of nitrogenous substances.

The fattening caused by a diet rich in starch and sugar may partially be due to the oxidation of these substances saving the fatty tissues from destruction, and allowing the fat in the diet to form new fatty tissues.

Although the functions of the fats and carbo-hydrates in the economy are very much the same, they are not mutually replaceable under ordinary conditions, if health and vigour are to be maintained at their maximum. Where men are much exposed to very cold temperatures and undergo great fatigue in the open-air—as during Arctic expeditions—a diet of albuminates, fats, salts, and

water (without carbo-hydrates) may maintain them for a time in good health; but the deprivation of fat from the diet under any circumstances is not well borne, and leads rapidly to loss of health and vigour.

It also appears that the carbo-hydrates are concerned with the maintenance of the proper reactions of the various bodily fluids (blood, lymph, gastric juice, urine, etc.). They give rise to lactic and other similar acids in the body, which act upon the alkaline phosphates, chlorides, etc., and elaborate the various acid juices characteristic of the different bodily secretions and excretions. Starches and sugars have much the same dietetic value. Cellulose is unchanged by the human digestive processes, and passes out as such in the fæces.

It is evident, therefore, that a diet which is to maintain proper bodily health must contain all the three substances —albuminates, fats, and carbo-hydrates. The albuminates are the most indispensable, as without them vital action must cease for want of a supply of nitrogen. But a diet of albuminates, salts, and water, alone, is rapidly destructive of healthy action. As before explained, the excessive waste resulting from the metabolism of so much nitrogenous food, necessary to maintain animal heat and energy, overtaxes the system, and imperfectly oxidized substances accumulate in it, which pervert healthy action and eventually set up diseased processes.

Vegetable Acids.—They exist in fresh vegetables and fruit, probably also in fresh meat and milk, in combination chiefly with alkalies as alkaline salts. These acids form carbonates in the system, and preserve the alkalinity of the blood and other fluids. This is their chief function, but they may also furnish a small amount of energy and animal heat by oxidation. If these substances are absent in a diet, the blood becomes impoverished, and scurvy

results. It is maintained, however, by some authorities that the presence of fresh vegetables or lime-juice is not alone sufficient for the prevention or the cure of scurvy, and that the disease is essentially due to poisoning by the ptomaïnes of tainted animal food.

Scurvy, although formerly very fatal to crews of ships on long voyages, and to populations on shore during times of want and famine, can hardly be called now a disease of modern life, when fresh meat, vegetables, and fruit are within the reach of all classes. Such is the case at least with adults; but infants, fed exclusively upon condensed milk or preserved foods, have lately been shown to suffer from a form of scurvy. The hæmorrhages characteristic of scurvy take place under the periosteum of the long bones. The disease is often associated with rickets, and is generally rapidly cured by the administration of fresh milk and fresh food.

The *mineral salts* are essential for the growth and repair of all the tissues of the body. The phosphates of lime, potash, and magnesia contribute largely to the formation of bone; whilst iron for the red blood corpuscles and colouring matters, chlorine for the gastric juice, potash for the blood cells and solid tissues, and soda for the intercellular fluids, are all indispensable. Mineral salts are required in diets for all ages, but more especially for infants and children, when not only has waste to be made good, but new material for the growth of the body has to be supplied.

Water is a component part of all the so-called solid foods, and is likewise taken separately, the amount of water contained in the solid foods of an average diet being insufficient for the needs of the body. The water contained in different food stuffs varies within very wide limits; in some articles it amounts to not more than

12 per cent. by weight, while in others it may reach 90 per cent. Water is necessary to make up the losses occasioned by its excretion in the breath, sweat, urine, and fæces, and to renew all the various fluids and solid organs of the body, into whose constitution water largely enters. Water also serves as a vehicle for the solution and dilution of the solid foods, whereby they are more easily digested and assimilated, and is essential for the elimination of many waste products.

Diet.

From physiological experiment and calculation from dietaries of different kinds, tables of diets, giving the amounts of the proximate constituents of food necessary for an adult under varying conditions, have been constructed; but there is considerable discrepancy among physiologists regarding the qualitative and quantitative composition of these diets. Thus, there is a subsistence diet, calculated as sufficient for the internal mechanical work of the body alone; a diet for ordinary work (consumption of visible energy equivalent to 300 foot-tons per diem); and a diet for laborious work (450 to 500 foot-tons daily)—all suitable for a man of average size and weight (150 pounds). The following table is compiled from the researches of Playfair, Moleschott, Pettenkofer, Voit, and Ranke.

	Subsistence.	Ordinary Work.	Laborious Work.
	Oz. Av.	*Oz. Av.*	*Oz. Av.*
Albuminates	2·0	4·5	6·5
Fats	0·5	3·5	4·0
Carbo-hydrates	12·0	14·0	17·0
Salts	0·5	1·0	1·3
Total water-free food	15·0	23·0	28·8

The above quantities represent dry food. Ordinary solid food contains on an average 50 to 60 per cent. of water, so that the above quantities must be rather more than doubled if the diet is stated as so-called solid food (not water-free). About 50 to 80 ounces of water daily are in addition taken into the system in a liquid form, the quantity depending upon the amount of exertion undergone, and the temperature and humidity of the air. Thus, for subsistence a man requires about $\frac{1}{10}$ ounce of water-free food for each pound of body weight, and for ordinary work about $\frac{1}{7}$ ounce.

By the following table, which shows the approximate percentage composition of some of the more ordinary articles of food, it is possible to calculate a diet consisting of some of these common foods.

	In 100 Parts.			
	Albuminates.	Fats.	Carbohydrates.	Salts.
Raw meat	20·5	8·5	—	1·5
Hens' eggs	13·5	11·5	—	1·0
Cow's milk	4·0	3·5	4·5	0·7
Butter	1·5	83·5	1·0	1·5
Cheese	28·0	23·0	1·0	7·0
Bread	8·0	0·5	50·0	1·5
Potatoes	2·0	0·1	21·0	1·0
Oatmeal	12·6	5·5	63·0	3·0

Supposing a diet of meat, bread, and butter is required for a body of men in ordinary work.

Let x = amount of meat required in ounces per head, per diem.
y = amount of bread ,, ,, ,, ,,
z = amount of butter ,, ,, ,, ,,

Then $\frac{20·5}{100}x + \frac{8}{100}y + \frac{1·5}{100}z = 4·5$ (albuminates),

$\frac{8·5}{100}x + \frac{0·5}{100}y + \frac{83·5}{100}z = 3·5$ (fats),

$\frac{50}{100}y = 14$ (carbohydrates).

These equations, when solved, give the required amount of meat as 10·8 ounces, the bread as 28 ounces, and the butter as about 3 ounces.

The amount of nitrogen in the diet for ordinary work is 315 grains, and the amount of carbon 4,790 grains. One-tenth of the total nitrogen eliminated leaves the body in the fæces; the kidneys eliminate about 500 grains daily in the form of urea; and the skin and lungs give off a trace in the form of ammonia.

One ounce of albumin contains 70 grains of nitrogen and 212 grains of carbon, an allowance being made for the carbon which is excreted as urea, and which may be considered to be oxidized as far as carbonic oxide only. One ounce of fat contains 336 grains of carbon, and an ounce of carbo-hydrates about 190 grains of carbon.

In the best diets the proportion of nitrogen to carbon should be about as 1 to 15.

The *energy* obtainable from the different articles of food is expressed as so many foot-tons per ounce consumed. It is the amount which would be produced theoretically, if the constituents of the food were completely oxidized to carbonic acid and water; and the energy derivable from different food stuffs can be calculated from the heat required for their complete combustion—as measured in a calorimeter. It is evident that such theoretical expressions may have little bearing upon dietetic value, which depends so largely upon the digestibility and capability of assimilation possessed by the different food products. In the case of albuminates also, a portion passes out incompletely oxidized in the form of urea. The figures usually given are:

One ounce of dry albuminate yields 173 foot-tons of potential energy.

One ounce of fat yields 378 foot-tons of potential energy.

One ounce of dry carbo-hydrate yields 135 foot-tons of potential energy.

According to these figures, the average daily diet for ordinary work is capable of yielding 3,977·5 foot-tons, or in round numbers close upon 4,000 foot-tons. A large proportion of this theoretical energy, viz., about 2,500 foot-tons, is devoted to the maintenance of the body temperature, and to the performance of the various bodily functions, when the body is in a state of rest.

In a state of rest a man of 150 pounds weight gives off about 15 cubic feet of CO_2 gas in twenty-four hours. The production of 1 cubic foot of CO_2 by combustion is equivalent to 160 foot-tons of energy. Therefore $15 \times 160 = 2,400$ foot-tons of energy are consumed in the production of 15 cubic feet of CO_2.

Then again, if the average temperature of the air is taken as 50° F., the difference between the temperature of the human body (98° F.) and that of the air is 48° F. If, then, we consider the human body as absorbing and losing heat like water, the energy required to support a temperature of 98° F. in a man of 150 pounds weight is

$$\frac{150 \times 48 \times 775}{2,240} = 2,490 \text{ foot-tons.}$$

The number 775 is Joule's equivalent, *i.e.*, the number of foot-pounds of energy necessary to raise 1 pound of water 1° F.

These two methods of estimating the amount of energy necessary to sustain human life are seen to produce very similar results, viz., 2,400 foot-tons in one case, and 2,490 foot-tons in the other. The subsistence diet given in the table (p. 394) is capable of yielding 2,155 foot-tons

of energy. Playfair's subsistence diet (2·5 oz. alb., 1 oz. fat, 12 oz. carb.-hyd.) is, however, capable of yielding 2,430 foot-tons of energy, which is nearly identical with the results of the two methods just described.

The average diet, as before said, yields 4,000 foot-tons of energy (nearly). If 300 foot-tons is taken as the energy consumed in actual physical labour, then $4{,}000 - 300 = 3{,}700$ foot-tons are consumed in supplying energy for the functions of the body in a state of physical activity. This would mean that during ordinary work the production of CO_2 is raised from 15 cubic feet to an average of 23 cubic feet in the 24 hours; or supposing the man works for 8 hours and rests for 16 hours, then the CO_2 produced in the 8 hours of work is 11·8 cubic feet (1·47 cubic feet per hour), and in the 16 hours of rest 11·2 cubic feet (0·7 cubic feet per hour). In the same way the diet for hard (laborious) work produces 4,930 foot-tons of energy: subtracting 500 for actual visible work, there is left 4,430 foot-tons for the work of the body, equivalent to the production of 27·6 cubic feet of CO_2 in 24 hours, or 1·6 cubic feet per hour for 12 hours of work, and 0·7 per hour for 12 hours of rest.

When food is taken in large excess of the requirements of the system, a considerable portion remains undigested; fermentative and putrefactive changes are set up in the undigested mass as a result of the activity of the bacterial organisms always present in the intestinal canal, fœtid gases containing sulphur and carbon are formed, and dyspepsia and diarrhœa are provoked. Some of the products of putrefaction — possibly the alkaloids already referred to, the ptomaïnes and leucomaïnes—are absorbed into the blood, and cause fever, torpor, headache, and fœtid breath. Excess of fats and

starches tend to produce acidity and flatulence, whilst taken habitually in excess they may cause excessive formation of fatty tissues and obesity. In all cases of overeating, undigested muscular fibres, fat, and starch cells may be found by microscopical examination in the fæces to an unusual extent, and occasionally albumin and sugar will be found in the urine.

Deficiency in all the constituents of a diet tends to produce loss of weight, debility, prostration, and anæmia. If carried to the point of starvation, low fever and gastric disturbances are often excited, ending eventually in death. It appears, however, that some constitutions can withstand long periods of fasting (thirty to forty days), if plenty of water is taken; perfect health being maintained the whole time, although with gradually increasing emaciation and debility. The elimination of urea is always markedly diminished. The absence of fat in a diet leads to a state of malnutrition, possibly predisposing to such diseases as tubercle, especially in children and young persons. The deprivation of starches can be borne for a long time if fat is given; but little is known as to the ultimate effects of such deprivation, for wherever food can be obtained at all, the starchy constituents, so widespread and abundant in Nature, are sure to be largely represented.

The considerations which will influence the selection of a diet are many. They may be briefly summarized as follows: (1) Age. It is generally held that a child of ten requires half as much, and a child of fourteen quite as much, as a woman. An average diet for a child between eight and fourteen years of age should contain about 6 ounces of meat, 14 ounces of bread, 6 ounces of potatoes, 9 ounces of milk, and small quantities of butter, fresh vegetables, tea or coffee. A generous diet for a

working man would contain 9 ounces of meat, 18 ounces of bread, 16 ounces of potatoes, 16 ounces of milk, 2 ounces of butter or dripping, and 3 ounces of oatmeal. Old people should be given somewhat less proteid (about 15 per cent. less) and carbo-hydrates, and slightly more fat, than those in middle life. (2) Sex. Women require on an average one-eighth less food than men. (3) Selection of food. In making the selection, the local market will have to be studied; and it is essential to furnish a sufficient variety of food. The digestibility of various articles of food must also be taken into account. On an average, about 5 to 10 per cent. of all the common food stuffs is indigestible. (4). What is of prime importance is to see that the dietary allotted to each day contains the proper amounts and relative proportions of albuminates, fats, and carbo-hydrates; whatever the food selected, the salts will always be in sufficient quantity. In distributing meat rations it must be borne in mind that 20 per cent. of the gross weight must be deducted for bone. As to (5) meals, it is the usual practice to provide four meals daily: breakfast, dinner, tea, and supper—at intervals of about four hours, although three meals a day is probably more wholesome for an adult.

The Feeding of Infants.

Until the child is at least seven months old nothing but milk should be given, for it is unable to digest starch and other foods. The following instructions may be advantageously followed, at the earlier ages, in cases where the mother is unable to suckle her infant, and at the later ages in all cases:

(*a*) During the first six weeks after birth the child should be fed every two hours throughout the day,

reckoned as between 4 a.m. and 10 p.m., and once between these hours in the night. Its food should consist of one part of fresh, pure cow's milk and two parts of water, mixed and boiled, and after boiling sweetened with a small teaspoonful of brown sugar to each pint of the mixture. Barley-water may sometimes with advantage be used instead of plain water, but lime-water is better avoided. The mixture should be kept in a clean, covered vessel, and in a clean, cool place, between meals. The temperature of the food given to a young child should be about the heat of the human hand. Three to four tablespoonfuls should be given to a child each time it is fed.

(*b*) From the age of six weeks to three months the child should be fed with a mixture of equal quantities of cow's milk and water, with sugar as above; but two teaspoonfuls of cream may now be advantageously added to each meal. The quantity given at each meal should be about eight tablespoonfuls. The interval between meals should now be gradually but continually lengthened.

(*c*) From the age of three months to seven months the child should have a mixture of two parts of cow's milk to one of water. About eight tablespoonfuls should at first be given at each meal, but the intervals between meals being still lengthened, a larger quantity than this will soon be required. The quantity of cream given with each meal may now be increased from two to three or four teaspoonfuls. The infant should now only be fed during the night if it happens to awake.

The following is a useful working rule for the feeding of a child during the period in which liquids should be exclusively given: Begin with about thirty-two table-spoonfuls a day, as above (*a*), and increase this by the

addition of two to four tablespoonfuls a week up to the end of the seventh month.

(*d*) From the age of seven months to twelve months, the child should be fed every three hours, between 6 or 7 a.m. and 9 or 10 p.m. Each meal should consist at the first of about ten to twelve tablespoonfuls of undiluted cow's milk, with cream as above (*c*); but three of the meals may also each contain about a teaspoonful or more of baked flour or arrowroot, or of some infant's food, well boiled and stirred up with the milk.

(*e*) From the age of twelve months to eighteen months the child should still be fed about every three hours, between early morning and night. The amount of milk should be about twice as great as that given under (*d*); and porridge, bread and milk, bread and gravy, bread and butter, and a lightly boiled egg occasionally, may be given with advantage, or in place of some of the milk, as time goes on.

When nine or ten months old, the child should, as a rule, be gradually weaned, but it is well not to commence in very hot weather, owing to the risk of summer diarrhœa.

Feeding-bottles should be boat-shaped, preferably with an opening at each end. They should be fitted with a short rubber teat, capable of being easily turned inside out for cleaning. The long feeding-tube usually found in use very quickly becomes foul, and should not be employed. Any milk left in a feeding-bottle after a meal should be at once emptied away. Two bottles should be used alternately, each bottle being boiled and rinsed immediately after use, and placed neck downwards to drain in a cool, clean place, so that no dust may get into it. Condensed milk is never so good for infants as fresh milk; if used at all, it should be condensed "whole"

milk. Condensed milk should never be given to an infant from a tin which has the words "skimmed" or "separated" upon the label, for such milk has been robbed of a very important nutriment, and a child cannot thrive on it, however much is taken.

It is harmful to give children tea, beer, spirits, or cheese, because they interfere with the powers of digestion; and teething powders or soothing syrups are dangerous because they often contain opium.

When an infant is fretful or suffering from indigestion or diarrhœa, it will often be found that it is having too much or too strong food, and is fed too frequently. By diminishing its diet or diluting the milk with a little extra water, and carefully attending to the proper feeding times, the child will often get well. If, in spite of every care, it continues so to suffer, proper medical advice should always be sought.

Dr. Reid has demonstrated statistically the evil that results from the prevailing practice in many manufacturing towns of mothers leaving their homes during the day to work in factories. Children are as a consequence deprived of their natural food and of the care of their natural guardians. An inquiry instituted by a Parliamentary Bills Committee showed that the amount of infant mortality, attributable to the practice of married women engaging in factory work, amounted to 21 per cent. Two remedies are suggested in the report, one being the extension of the period of compulsory absence from work after confinement required by the Factory Act, 1891, from one month to three; and the other, the establishment of day-nurseries or crêches by local authorities, for which a small payment should be exacted from the parents.

Homes for the reception of pregnant working women have been for some years in existence in many Continental

cities. The experience of these homes shows that cessation from labour for a fortnight or a month preceding confinement renders the pregnancy more likely to proceed to the normal term, and the infants in consequence are more fully developed at birth.

Meat.

Meat contains a large quantity of the nitrogenous substances, some fat, and salts—chiefly the chlorides and phosphates of potash. It is rapidly digested and easily assimilated, and hastens tissue metamorphosis.

The albuminates form about 20 per cent. of raw meat (beef), of which about 15·5 parts are digestible albumins, peptones, and extractives, the remaining 4·5 parts being indigestible.

Bones contain a large amount of nourishing material, viz., albuminates (gelatine) 24 per cent., fat 11 per cent., ash or mineral salts 48 per cent. A most nourishing soup can be prepared by boiling bones. The men in the "Eira" Arctic Expedition were fed almost exclusively on raw meat, and escaped scurvy.

In inspecting meat, the muscles should be found firm and elastic, of deep red colour—not purple nor pale, flabby, and sodden—and marbled with fat in well-conditioned animals. There should be no excess of moisture, no pus or fluids in the intermuscular cellular tissue, and no lividity on cutting the muscles across. The flesh must be quite free from deposits (tumours). The odour should be fresh and not unpleasant, without a suspicion of putridity or smell of physic. Meat which has commenced to putrefy is pale and soft; later it becomes green. If the odour of putrefaction is not otherwise apparent, a knife should be thrust into the meat up to the hilt and then held to the nose; or a little of the meat may be chopped

up and soaked in warm water. The fat should be firm and of a pale yellow colour, and free from hæmorrhagic points. Any lymphatic glands attached should be firm, slightly moist, and of a pale grayish-yellow colour on section; and the marrow of the bones should be light red. The lungs should be examined for inflammation or abscesses, tuberculosis, or actinomycosis; the liver for distoma or liver-fluke, tuberculosis, or hydatid tumours; and the spleen for enlargement or nodules.

The Important Parasites of Flesh.

CYSTICERCI.—The cysticercus, or "bladder-worm," causes the condition known as "measles" in the pig, ox, and sheep. When measly flesh is consumed by man, the "bladder-worm" undergoes a series of changes which terminate in its conversion into a tape-worm. In the flesh of the pig, and much more rarely in that of dogs, monkeys, or man, a number of small oval or round cysts are seen, occupying a position between the muscle fibres, and commonly varying in size from a pea to a cherry—though they have been found as small as $\frac{1}{25}$ inch, and as large as $\frac{3}{4}$ inch in diameter. These cysts are the *Cysticerci cellulosæ*—the bladder-worms which form a stage in the development of *Tænia solium*. They are surrounded by a pale milky-looking fluid, and the cyst wall shows a white spot (generally central) upon its surface. The affected flesh is pale, soft, unduly moist, and flabby, and it has a smooth slippery feel. Sometimes there is some degree of calcification of the capsule, the result being that, when sections are cut, a grating sensation is experienced.

The bladders should be incised with a sharp knife, and the worm examined by a powerful hand lens, when at one extremity will be found the blunt square head

provided with a sucker at each "angle," and a fringe of hooklets placed more centrally. These hooklets are very characteristic, and must always be found before a definite diagnosis is ventured on.

Those cysts that are dried up and indistinct can be made visible by soaking in weak acetic acid. Ostertag attaches great diagnostic importance to the rounded or oval calcareous corpuscles, which are so generally embedded in the tissue of the head, but which disappear on the addition of acetic acid.

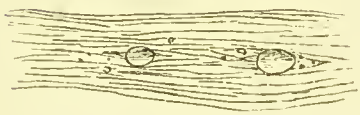

FIG. 49.—"MEASLY" PORK, SHOWING (DIAGRAMMATICALLY) ITS APPEARANCE TO THE NAKED EYE.

FIG. 50.—HEAD OF TÆNIA SOLIUM. (Obj. ½ inch.)

Young pigs are more especially liable to be attacked; and during life the earliest evidence of the parasites is afforded by the presence of one or more small cysts in the conjunctiva, or in the loose tissue of the frænum linguæ. After death the liver and the muscles of the shoulders, intercostals, and loins, are seen to be chiefly affected.

The Cysticercus of the Ox.—Cysticercus bovis, or "beef-measles," which chiefly affects the calf, possesses a flat head armed with no hooklets, but simply with suckers, around which there is frequently a considerable deposit of pigment, and on the surface of the head there is a pit-

like depression ("frontal suction cup"). It develops in man into the adult tape-worm called *Tænia mediocanellata*, which is longer than *T. solium*, and appears to be more prevalent in this country.

Bothriocephalus latus, a tape-worm which is almost limited to certain parts of the Continent of Europe, is even larger than *T. mediocanellata*. It has a club-shaped head, not armed with hooklets, but possessing two deeply grooved longitudinal suckers, one on each side.

Tænia echinococcus is the small tape-worm, of three or

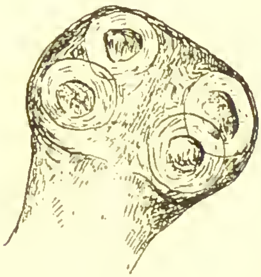

FIG. 51.—HEAD OF TÆNIA MEDIOCANELLATA.
(Obj. ½ inch.)

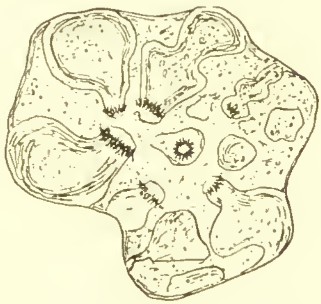

FIG. 52.—BROOD CAPSULE OF AN ECHINOCOCCUS.

four segments, which is commonly found in the dog. The encysted form ("hydatids") is generally found in the lungs and liver of oxen, sheep, and swine, and (more especially in Iceland) in man. The hydatids consist of thin pale vesicles floating in a clear liquid, the whole being encysted in a tough capsule. The inner lining of the capsule consists of ciliated epithelium; and from the inside of the cyst wall there generally arise many so-called "brood capsules" (Fig. 52).

The condition is diagnosed with certainty by the microscope, either by the discovery of the characteristic heads or of detached hooklets in the clear liquid of the

cyst. Valuable corroborative evidence is furnished by the fact that the liquid is quite free from albumin, and, in consequence, does not coagulate on boiling.

TRICHINA SPIRALIS.—This parasite has been found in the flesh of many different animals (pigs, pigeons, eels, etc.), but most commonly, by far, in that of pigs. Oxen and sheep do not suffer from attack by these nematodes.

The shape of the minute worms is nearly that of a typical nematode, *i.e.*, a slender rounded body tapering

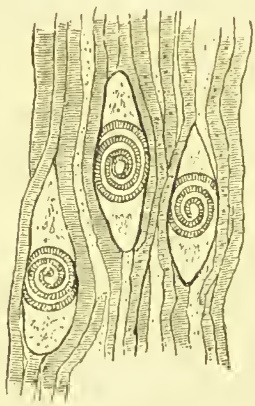

FIG. 53.—TRICHINA SPIRALIS, ENCYSTED IN MUSCLE.
(× about 40 diameters.)

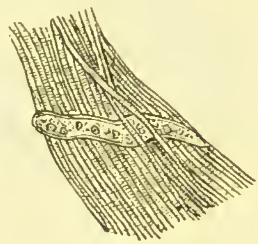

FIG. 54.—ONE OF RAINEY'S CAPSULES.
(× 285.)

gradually at either end. The extremity which constitutes the head proceeds to a long slender point having a small central orifice—the mouth; the other extremity, the tail, ends more bluntly. The worms possess a distinct alimentary canal, and even rudimentary sexual organs are present. In the female a uterus is discernible, which will frequently be seen to be full of minute free embryos curved upon themselves; these latter have been observed to become extruded from the vagina, and subsequently to move sluggishly about the field of the

microscope. The male worm is much smaller than the female, and is only about $\frac{1}{16}$ inch long when mature; the female reaches to $\frac{1}{8}$ inch. The long slender head and blunt tail are two characteristics which serve to distinguish these worms from parasites which otherwise resemble them, such as *Dracunculus* and *Filaria sanguinis hominis*.

The small worms are mostly coiled up in cysts, so disposed that their longest diameter is in a line with the muscular fibres; and a drop of acid will stimulate them to transient movements if they are alive. These cysts lie between the muscle fibrillæ, and their walls are sometimes partially or completely calcified, so as to give a grating sensation when the finger is passed over a section of the flesh. This calcareous deposit serves to shield the parasites from the destructive consequences of salting, and to a slight extent also from heat when the flesh is being cooked. There may be from one to three trichinæ in a cyst. Frequently 25 per cent. of these parasites when present are encysted in the diaphragm; and therefore, when possible, a piece of this muscle should be procured. The back muscles, on the other hand, are the least attacked.

Either a section may be made of the muscle, or it may be teased out with needles; and preferably, in the case of a long muscle, a point near its insertion should be selected for teasing—since this is a favourite site for encystment. The affected muscle is seen to be pale and œdematous; and, if the worms are encapsuled, small, rounded (or, more truly, lemon-shaped), whitish specks, averaging about the size of a very small pin's head, are visible to the naked eye. These can be made very distinct by means of a hand lens; but a low power of the microscope should be employed in every case. The most characteristic appearance will be got by making a

thin longitudinal section of the affected muscle, and immersing this in potassic hydrate solution of medium strength — which serves to make the muscle fibres transparent, and leaves the worm exposed in its coiled condition within the capsule. The soaking should not be prolonged beyond a minute or two, or the worm itself will also be cleared up. Glycerine is a good mounting medium when a permanent specimen is desired. Sometimes, owing to considerable calcareous deposit in and around the walls of the capsule, a view of the worm is obscured; in these cases a drop of dilute hydrochloric acid, run under the cover-glass, will dissolve this deposit; or if, as is sometimes the case, one or more oil globules partially obscure the worm, a drop of ether, applied in a similar manner to the acid, will clear away the fat. There are generally oil globules at the poles of the capsule.

The parts of the body which are most likely to be affected will easily be remembered if it be borne in mind that the worms migrate to their settlements from the gastro-intestinal tract, and chiefly from the commencement of the small intestine. The diaphragm, the liver, the intercostal and abdominal muscles, are necessarily the first encountered, and therefore suffer most; but in later stages of the infection there is rarely a muscle which may not be affected. It is also a common practice to make an effort to diagnose the presence of the parasites in the living animal, by examining the eyes and the under surface of the tongue, both of which will frequently show the small pinhead deposits.

The dangerous and often fatal disorder created by these worms, as they traverse the gastro-intestinal walls and travel to their encystment in the various organs of the body, is most prevalent in those countries where the un-

cooked or imperfectly cooked flesh of the pig is consumed, as in the form of sausages, ham, etc.

Hot smoking and efficient cooking destroy these parasites, but in the latter case the meat must be "done through"—*i.e.*, thoroughly cooked through the centre—or some of the parasites, especially when shielded by calcareous walls, may escape the temperature necessary to destroy them—that of 150° F.

There are certain small semi-transparent bodies, called "psorospermia," or "Rainey's capsules," which somewhat closely resemble trichinæ, presenting as they do small dark oval or elliptical bodies, of greater lengths, however, than encysted trichinæ. They are made up of a thick membrane, formed by small hairlike fibres arranged in lines, which encloses small oval—or, rather, kidney-shaped—granular cells, closely adherent together; and the whole lies embedded in the muscle substance itself, *i.e.*, the sarcolemma. They are extremely common, and may exist in the flesh of most of the animals used for human consumption, and apparently when eaten they do no harm.

Several more obscure bodies, the nature and significance of which we are still more ignorant of, may exist in flesh, such as bodies somewhat resembling pus cells, and others forming minute concretions or tiny hard nodules. Interesting as these are pathologically, they are rare, and when present even in considerable numbers do not appear to affect the wholesomeness of the meat to any degree.

ACTINOMYCOSIS.—The "ray-fungus" (actinomycosis), one of the "fission fungi," is now becoming recognised as a parasite of commoner occurrence in the ox than was once suspected. The difficulties which stood in the way of an earlier appreciation of this fact arose from the circumstance that both the ante- and post-mortem appearances of the disease closely simulate those of tuberculosis.

It has not yet been proved that the disease can be communicated by the flesh of animals (bovines) suffering from an attack, for the vitality of the fungus when exposed to heat is very slight. The subject is of such interest and importance, however, that a few additional facts are appended.

The parasites almost entirely affect the tongue, the jaws (especially the lower one), and the lungs, where they may be detected, by the naked eye, as small dirty white specks commonly about the size of a very small pea, but varying from the tiniest speck up to $\frac{1}{5}$ inch

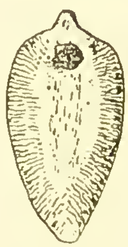

FIG. 55.—DISTOMA HEPATICUM. (Natural size.)

in diameter. The parasites assume, when encysted, a peculiar symmetrical appearance, due to the fact that they consist of small linear elements, thicker at one extremity than at the other, and are so arranged that their smaller extremities are all directed towards a central point; the stellate or rayed appearance thus created is sometimes remarkably regular and uniform. The tongue when affected is hard and swollen, and presents the flattened nodules chiefly upon its dorsal aspect.

DISTOMA HEPATICUM.—To examine for these parasitic trematodes the liver should be taken, and the bile-ducts carefully exposed. The parasites will be found as small organisms of a pale-brown colour, in shape like little soles, and provided at their broad extremity with a

sucker for attachment to the walls of the bile-ducts. Their surfaces are beset with many little warty points, and they average in size from 1 to 1½ inches in length, and about ½ inch in width; they generally attach themselves to the biliary ducts, but they may be found also in the parenchyma of the liver.

The Life-histories of the Animal Parasites of Man.

Tænia solium.—Portions of the ripe proglottides of the fully matured tape-worm are swallowed by pigs, or more rarely by dogs, monkeys, or man. Very commonly the ova they contain escape and become scattered—some into water, others upon grass or vegetables, where they may certainly survive for some days. If the eggs are ingested, on reaching the stomach the shell becomes dissolved by the gastric juice, and the embryo (a globular body armed with three pairs of hooklets) bores its way through the stomach or intestinal walls, and finally comes to rest in some part of the body. It then grows in size, loses its six hooklets, and after a time develops a head provided with four suckers, and armed with a circle of minute hooklets ("bladder-worm," or *Cysticercus cellulosæ*). The head grows out from the inside of the bladder, to the wall of which it is attached by a constricted part known as the neck or pedicle. The parasite may remain in this condition for long periods, or may shrivel up and die, for it is incapable of further development until it is ingested by a carnivorous animal. When this occurs, on reaching the alimentary canal, it projects its head and neck (by invagination), the bladder part is dissolved by the gastric juice, and very shortly transverse lines appear on the neck, which increase in size and so separate from each other, until after a few weeks a jointed

adult tape-worm results, with proglottides charged with ova ready to commence a fresh cycle.

The life-histories of *Tænia mediocanellata* and *Bothriocephalus latus* are similar to that of *T. solium*; but the bladder-worm of the *Bothriocephalus latus* is supposed to inhabit some species of fish (perch, pike, and salmon-trout ?), or possibly a fresh-water mollusc.

Distoma hepaticum.—The ova develop, in water, into ciliated embryos, and these undergo in small water-snails (*Limnæus truncatulus*) a further development into larvæ. These larvæ ultimately become little organisms resembling tadpoles (*cercaria*), which either remain encysted in water-snails, or leave them and become attached to grass. They are generally taken up by grazing sheep, but very rarely man also becomes a host.

Tænia echinococcus.—Of the three or four segments of this tape-worm the last one only contains sexual organs. The ova are discharged with the fæces (commonly of dogs), and they probably infect cattle, swine, and man through the medium of water or raw vegetables. On entering the stomach the gastric juice dissolves the shell of the ova, and liberates the embryos, which possess six hooklets in two rows; by means of these hooklets the embryo bores its way through the walls of the intestine and develops, chiefly within the liver, into so-called "hydatid cysts"; *i.e.*, the hooklets are lost, and the formerly solid embryo swells out into a vesicle. Generally a number of protrusions ("daughter cysts") grow from the interior of the vesicle, which itself forms a cyst ("mother cyst"). To the mother cyst the daughter cysts are attached by a pedicle, which ultimately becomes detached. Each "daughter cyst" may develop "grand-daughter cysts," and thus the original echinococcus may become full of small cysts of varying sizes ("pill-box

hydatids"). Finally the little buds develop into "brood capsules," *i.e.*, thin-walled sacs which remain attached by a pedicle, each sac developing a number of heads, with four suckers and a row of hooklets apiece.

Thus the encysted form of these parasites possesses the distinguishing feature of being able to give rise to a large number of scolices, most of which are capable of developing into the adult worm when they enter another host.

Rarely the hydatid throws out protrusions externally.

Ascaris lumbricoides (the round-worm).—The ova of the females are discharged with the fæces of the host, and then they become capable of furnishing embryos, a power not hitherto possessed. The embryos probably have an independent existence (possibly in water or in some intermediate host—such as worms or insects) before again entering the human body, and completing their development. The parasites inhabit the small intestine, are of a brownish-yellow colour, and are most commonly met with in people who live amid dirty surroundings.

Oxyuris vermicularis.—These fine, white, thread-like parasites occupy the large intestine. The ova, unlike those of *A. lumbricoides*, contain embryos prior to their discharge; but probably these are incapable of further development until they have passed with the fæces, when they may reinfect the same individual or others occupying the same bed, etc., or may pass into water, or become deposited upon vegetables and fruit, and thus again become ingested.

The life-histories of *Trichocephalus dispar* (whip-worm) and *Schlerostomum duodenale* (common in Egypt and Brazil) have not yet been definitely ascertained. It is not yet certain by what vehicle the ova of the females (which develop in man) infect their host, or whether in

either case there is an intermediary stage of development of the parasite.

Bilharzia hæmatobia.—The male is a white flattened worm, $\frac{1}{2}$ inch in length ; posteriorly the sides of the parasite curve towards each other, and meet to form a channel, in which the long slender female ($\frac{3}{4}$ inch in length) lies during fecundation. The ova possess a beak, which generally projects from one end, but sometimes laterally. These ova may be hatched before the parasite leaves the tissues of the original host, but the embryos are not born until afterwards. If the ova find their way into water, their walls swell up and rupture, and the minute embryos escape, armed with cilia, which serve to project them through the water. Probably the embryo becomes attached to some fresh-water mollusc (or possibly some fish), and, developing into a cercaria form, is ingested as such by man, and then completes its cycle of development.

Trichina spiralis.—When trichinous meat is consumed, the trichina embryos (averaging a little over 0·1 mm. in length), which resemble small filariæ, bore their way through the intestines and reach the tissues. They always become encysted in muscle fibres, where they increase in size (up to 0·6 to 1 mm. in length), and acquire an alimentary canal and sexual organs. The encysted worms remain quiescent for long periods, and may ultimately die ; but if trichinous flesh is eaten they give origin, through their embryos, to a fresh cycle of existence.

Horseflesh.

By the Horseflesh Act, similar powers to those of the Public Health Act (1875) are given as to the inspection, examination, and seizure of horseflesh sold for human

food, and which is not legibly labelled "Horseflesh." It becomes necessary, therefore, in order to check fraud, to be familiar with the chief differences which exist between the meat of the ox and that of the horse. In horseflesh the meat is of a darker red, and sometimes brownish in hue; it is coarser—the muscular fasciculi being broader—than in oxflesh; the odour of the fresh meat is different, and after the lapse of a day or two, as the flesh dries, it develops a peculiar faint odour, and imparts a soapy feeling to the fingers. The fat is more yellow and soft, and possesses a sickly taste, and, in consequence, it is sometimes removed and replaced by ox-fat, which is skewered on to the meat. If the bones have not been removed, they will afford an additional clue, inasmuch as they are larger, and their extremities (tuberosities, etc., for the attachment of muscles and ligaments) are larger and more marked, these signs being additional to some anatomical differences in the construction of the horse's skeleton.

The tongue and the liver of the horse, together with some other organs, are also occasionally made to do duty for the corresponding organs in the ox. The tongue of the horse is, however, broad and rounded at its free end, instead of pointed, as in the ox; and if the hyoid bone is attached, it is found to be made up of five parts, whereas that of the ox consists of nine. The epiglottis is, moreover, smaller and more pointed in the horse. The liver, whether of the ox or sheep, consists of one very large lobe and another relatively small one; in the horse there are three large and distinct lobes, and a fourth which is very small.

Cooking.

The *cooking* of meat is necessary (1) to destroy any noxious organisms or poisonous bodies that may be

present in raw meat; (2) to preserve it from putrefactive changes by heat sterilization; and (3) to increase its digestibility and produce that palatability which a civilized taste demands. In all cooking processes meat loses weight, usually from 20 to 30 per cent. In *boiling* a joint, the meat should be plunged into boiling water for five minutes to coagulate the outside albumin and retain the salts, extractives, and soluble substances, in the interior. The remainder of the boiling should be conducted at a temperature below 170° F.—which is the temperature at which most of the albuminates coagulate —in order that the meat may not become tough, dry, and indigestible. On the other hand, in making broth the meat should be cut into small pieces, and placed in cold water, which is gradually warmed to 150° F.; in this way the salts and extractive matters pass out of the meat into the broth, together with a certain proportion of the more soluble albuminates. A final heating to a boiling temperature is advisable, if there is any suspicion of taint in the stock meat, in order that putrefactive organisms may be destroyed.

In *baking* and *roasting*, the joint of meat should first be subjected to an intense heat, to coagulate the outside albumin and retain the soluble juices. After a few minutes the temperature should be lowered, and the roasting or baking completed at 180° F. to 200° F. The usual rule is to allow a quarter of an hour for every pound of meat. Aromatic products are formed in roasting and baking which are volatilized; some of the fat is melted and flows out of the joint together with gelatine and extractives to form the gravy.

The gas cooking ovens, which have now come so largely into use, present several advantages over kitchen ranges heated by coal. They are very cleanly; the

temperature of the oven can be regulated with great nicety by adjusting the consumption of gas; there is the convenience of the oven being ready for use in a few minutes after the gas is lighted; and as soon as the cooking is finished the gas can be turned out. It is very difficult to distinguish between a joint of meat baked in a gas oven and one roasted before an open fire, if the gas oven is properly ventilated and a flue is provided to carry off the products of combustion. If the ventilation is insufficient either in a gas oven or ordinary close range oven, the meat becomes sodden in its own vapours, and in the case of the gas oven also with the gas products, which give it a disagreeable taste and odour. Gas cooking stoves should be provided with Bunsen burners, arranged round the side of the oven at the bottom; and the oven walls should be double, the space between the plates being well packed with slag wool to prevent the radiation of heat. No soot is formed in gas cooking, and there are no dust, ashes, and dirt, as in a coal cooking range.

Meat can be *preserved* by drying in strips in the sun, called jerking; by salting; by canning, *i.e.*, by boiling the meat in tins, which are hermetically sealed by soldering at the boiling temperature, all germs being destroyed by the process of boiling, which should be repeated more than once to kill the spores; and by refrigeration in the raw state—a process now very largely used, the refrigerating chambers on board ship permitting of the importation into this country of meat from South America and the Australian colonies. The last process is by far the best, as the freshness and nutritive value of the meat remain unaltered. It is almost impossible for anyone to distinguish a New Zealand joint of mutton from the home product—if it is properly thawed before

being cooked. The low temperature of the ice-house (not less than 6° F. below freezing-point) does not destroy bacteria—the agents of putrefaction—but prevents their development. The preservation, for many ages, of the Siberian mammoth in its icy casing is a notable example of the antiseptic properties of great cold.

Frozen meat can generally be distinguished by the uniform colour of the meat, even the fat being stained by the exuded juices from the lean parts. The external surface of the meat is, moreover, duller and browner than that of fresh meat, and the joints are not usually so well dressed as in the case of home-killed meat.

Effects of Diseased or Unsound Meat.

It was formerly believed that thoroughly cooked meat is not likely to produce any injurious effects, even when derived from a diseased animal, or after putrefactive changes have commenced in it; but the most recent research rather tends to show that meat which is derived from a diseased animal, or which has become tainted by the presence of putrefactive bacteria, may possibly be cooked sufficiently to destroy the microbes themselves, whilst the ferments generated by the microbes give rise to poisonous substances unaffected by cooking. Tainted meat, eaten hot, is often harmless, but taken cold may produce symptoms of poisoning, the bacterial ferments having had time to act upon the albuminous substances of the meat. The temperature employed in boiling or baking may, therefore, be inadequate to destroy the poisonous properties such meat in a raw state may possess. Where the meat is only partially cooked, and underdone in the centre, danger is still more likely to arise; and in such cases symptoms of poisoning,

occasionally ending fatally, have been observed in those who have partaken of decomposing food. A large number of instances of meat-poisoning have been connected with the consumption of sausages, pies, and hams (Welbeck, Nottingham, etc.). The symptoms, which in most cases supervene in from six to eight hours, are those of violent irritation of the alimentary tract, and are characterized by acute vomiting, diarrhœa and colic, increased mucous secretions, cramps in the extremities, and failure of the heart's action. Whether these symptoms are produced by putrefactive bacteria or special bacilli in the food, or by the products of their action upon albuminous substances—the poisonous alkaloids, ptomaïnes, and albumoses—it is impossible to say. The latter explanation appears to have some probability from the fact that these attacks are very sudden in their onset, and commence very shortly after partaking of what is often apparently wholesome and fresh food—pointing, therefore, rather to the action of a chemical poison than of a bacterial organism requiring time for its growth and development—and that the symptoms of poisoning by the alkaloid muscarine present very nearly identical features with those observed in these cases.

Besides a muscarine-like poison, there appears to be another poison formed in decomposing flesh and fish, which produces symptoms analogous to those of atropine, viz., quickened pulse, paralysis of the muscles of the eyeball, and diminished secretion from the mucous membranes. This poison exerts an antagonistic effect upon the muscarine-like poison; and in different cases one of these poisons may predominate over the other, and produce its characteristic symptoms more or less modified. The presence of these alkaloidal substances may possibly account for the ill effects produced by

eating oysters, mussels, and some kinds of fish, such as mackerel, when out of season, and pork in hot climates.

There is a form of infective fever closely allied to enteric fever, the specific organism concerned (*B. enteritidis*) being first described by Gärtner as the cause of an outbreak of illness in 1888 affecting fifty-eight people, of whom one died. The illness was directly traced to the consumption of the flesh of an ox, which had prior to death suffered from diarrhœa. Many outbreaks of so-called meat-poisoning appear to have been due to the presence of this bacillus in the insufficiently cooked meat of diseased animals.

The balance of evidence is, however, in favour of diseased meat from cattle, sheep, and pigs being eaten with impunity, if thoroughly cooked. But there can be no reason why diseased meat should be allowed to be used for human consumption, and it is very properly condemned in this country wherever exposed for sale.

There are certain diseases of animals which are known to be, or believed, on good grounds, to be transmissible to man. These are anthrax or malignant pustule, tubercle, foot and mouth disease, rabies, glanders and farcy in horses, *Cysticercus cellulosæ* and *bovis* in the pig and ox respectively, and *Trichina spiralis* in the pig. With the exception of cysticercus and trichina, all these diseases are far more frequently transmitted to man by other means than by the consumption of diseased flesh. But it must be remembered that such transmission is possible in respect of several diseases, and would probably be much more frequent than it is, were it not for the precautions taken to prevent the sale of unsound meat, and for the safeguard of cooking. In all other diseases it is generally held to be sufficient to condemn the affected parts, if the rest of the carcass appears healthy.

In investigating a case of food-poisoning, it is best to enter on a paper every article that has been consumed in the affected household or households, and then by a process of exclusion to determine the article or articles that have been eaten in common by the sufferers. The article must then be traced and secured, and the correctness of the conclusion confirmed by feeding experiments with it on one of the lower animals.

The Report of the Royal Commission (1895) appointed to inquire into the effect of food derived from tuberculous animals on human health, is worthy of careful study. As regards the prevalence of tuberculosis in food animals, the records of the Copenhagen and Berlin slaughter-houses show that from 15 to 18 per cent. of the oxen and cows slaughtered are tuberculous, of calves only from 0·1 to 0·2 per cent. are tuberculous, of sheep only 0·0003 to 0·004 per cent., and of swine 1·55 to 15·3 per cent., the latter figure applying to the Copenhagen and the former to the Berlin swine. For milch-cows there are no figures available on a large scale; but of 300 milch-cows which were slaughtered in Edinburgh in 1890, on account of the appearance of epidemic pleuro-pneumonia there, 120, or 40 per cent., were found to be tuberculous on post-mortem examination. There is no doubt that milch-cows suffer far more frequently than oxen, heifers, or bulls, and that tuberculosis is more frequently found in the carcases of cows than in any other animal slaughtered for sale. From the experiments made for the Commission by Dr. Sidney Martin, it would appear that tuberculous deposits are but seldom found in the meat substance—the muscular tissue—of the carcase of an affected animal. They are principally found in the organs, membranes, and glands. In cases of mild, moderate, and localized tuberculosis, if great care is exercised to

prevent smearing and contamination of the meat by caseous or other tuberculous material adhering to the butcher's hands, knives, and cloths, there is no reason why such meat should not be used for human consumption. As at present practised, however, in this country, the slaughtering of a tuberculous animal almost necessarily involves the contamination of the surfaces of the joints of meat with infective tubercular material. In cases of generalized tuberculosis, not only is the risk of contamination of the meat in dressing the carcase greatest, but there is also no certainty that tubercular material may not be present in the muscular substance, or in glands in the connective tissue between the muscles, and consequently the carcases of animals so affected should be condemned and destroyed.

The necessity for skilled and well-trained meat inspectors is dwelt upon by the Commissioners, who were of opinion that the following principles should be observed in the inspection of tuberculous carcasses of cattle:

"(*a*) When there is miliary tuberculosis of both lungs (*b*) When tuberculous lesions are present on the pleura and peritoneum (*c*) When tuberculous lesions are present in the muscular system or in the lymphatic glands embedded in or between the muscles (*d*) When tuberculous lesions exist in any part of an emaciated carcass	The entire carcass and all the organs may be seized.

"(*a*) When the lesions are confined to the lungs and the thoracic lymphatic glands (*b*) When the lesions are confined to the liver (*c*) When the lesions are confined to the pharyngeal lymphatic glands (*d*) When the lesions are confined to any combination of the foregoing, but are collectively small in extent	The carcass, if otherwise healthy, shall not be condemned; but every part of it containing tuberculous lesions shall be seized.

"In view of the greater tendency to generalization of tuberculosis in the pig, we consider that the presence of tubercular deposit in any degree should involve seizure of the whole carcass and of the organs.

"In respect of foreign dead meat, seizure shall ensue in every case where the pleuræ have been 'stripped.'"

As regards cow's milk, the Commissioners found that there was no evidence of danger to the consumer, even when the milk is derived from a tuberculous animal, so long as there is no disease of the udder. But the affection of the udder may be present in a cow not otherwise markedly affected with tuberculosis; and the infection once implanted in the udder may spread with alarming rapidity. The milk of cows with tuberculosis of the udder possesses a high degree of virulence; and is virulent even when no tubercle bacilli can be demonstrated in it.

The Commissioners held that all udder diseases should be notified, and that anyone selling milk from a cow with diseased mammary glands should be liable to a heavy penalty; they advocate systematic inspection of cows by veterinarians as a means to this end. This recommendation was given effect to by the Dairies, Cowsheds, and Milkshops Order of 1899, by which Article 15 of the Order of 1885 is altered, so that the expressions in the article which refer to disease shall include, in the case of a cow, such disease of the udder as shall be certified by a veterinary surgeon to be tubercular. Such tubercular disease of the udder ought to be suspected when a painless hard lump, slowly enlarging, can be detected in one or more of the quarters.

Further recommendations of the Commissioners were to the effect that stock-owners should be encouraged to test animals by the gratuitous supply of tuberculin, and the offer of the services, free of charge, of a veterinary

surgeon; that better sanitary conditions should be enforced in cowsheds; that the closing of private slaughter-houses, and the enforced use of public slaughter-houses should be brought about, to insure a uniform and equitable system of meat inspection; and that foreign meat should be required to bear a mark of inspection and approval stamped upon it at the time of killing. They do not recommend compensation to the owners of condemned carcases.

The influence of cooking upon tuberculous meat and milk was investigated by Dr. Woodhead, who arrived at the following conclusions: "In the boiling and roasting experiments, as ordinarily carried out in the kitchen, the temperature, however high it may be near the surface, seldom reaches 140° F. in the centre of a joint, except in the case of joints under 6 pounds in weight. Ordinary cooking is quite sufficient to destroy any smeared (infective) material that remains on the outer surface of the meat, but it cannot be relied upon in the slightest degree to render innocuous the same smeared material when in the centre of a roll." Rolled meat, the central parts of which had become smeared by tubercular matter, were not sterilized by any process of cooking, unless the roll was less than 4 pounds in weight. The least reliable method of cooking, *quâ* sterilization, is roasting before the fire, next comes roasting in an oven, and then boiling.

Probably tuberculosis is not conveyed through the consumption of the flesh of tuberculous animals to any great extent. This view is supported by the fact that the reduction in the mortality from tuberculosis has been very marked during the age-periods in which meat is most largely consumed; and the enormous reduction in mortality, between 1851 and 1895, has been coincident

in point of time with an enormous increase in the amount of meat consumed in this country.

As regards the sterilization of tubercular milk, it would appear that absolute safety is only to be attained by raising the milk actually to the boiling-point. The Commissioners were of opinion that the innocence of tubercular milk treated in this manner was not entirely demonstrated to their satisfaction. When the tuberculous material in milk is raised to temperatures insufficient for the actual destruction of the virus, it is possible to obtain from the most deadly tuberculous material a weaker sort of tuberculous matter, so tardy in its operation upon test animals as to simulate the slower forms of consumption seen in the human subject, or when used to feed pigs—animals having some specialities of throat (tonsillar) structure like that of man—giving rise to chronic enlargements of the cervical glands, resembling the scrofulous glands so common in children. These observations, the Commissioners think, are suggestive of the possibility of widely prevalent forms of human tuberculosis having an origin in milk.

Bovine and porcine cysticerci, which develop *Tænia mediocanellata* and *Tænia solium* respectively in man, are probably little affected by salting and smoking. There is good ground for believing that exposure for some minutes to a temperature above 150° F. destroys them. The same may be said for the *Trichina spiralis;* only the temperature must be somewhat higher, as the worm is surrounded by a dense capsule which prevents the heat reaching it.

The meat of animals which have been slaughtered in the early stages of acute inflammatory disease and epidemic pleuro-pneumonia is probably quite wholesome if well cooked, unless the animals have been drugged

with medicines before killing. The evidence as regards the possible bad effects from the use of meat taken from animals which have suffered from rinderpest or cattle plague, braxy or splenic apoplexy (sheep), and small-pox (sheep), is conflicting.

A certain amount of the meat condemned in public slaughter-houses may be used for human food under the following circumstances: (1) It may be dealt with in public kitchens under precautions which will insure a thorough cooking, and the cooked meat or soup made therefrom may be sold at a small charge—as in the Frie-banks in Germany, or (2) the meat can be sterilized by steam under pressure, and then sold. If, however, it is unfit for human food under any circumstances, it should be either made into manure under supervision; or, failing this supervision, it should be saturated with petroleum, carbolic acid, or mineral acids, before it is allowed to be removed.

The arguments in favour of public abattoirs may be summarized as follows: They constitute the only possible means of proper and systematic inspection at the time of slaughter, such inspection being necessary to prevent the sale for human food of diseased meat. The consumer would have a guarantee that home-killed meat was good and wholesome, and this would probably increase the demand for it. The better provisions for slaughtering and cooling the meat, and the diminished handling, favour its good appearance when exposed for sale. If public slaughter-houses are constructed near railway-stations, the driving of cattle through crowded streets is avoided. On the other hand, butchers as a body do not favour these establishments; and slaughtering is likely to be done elsewhere, unless private slaughter-houses are at the same time abolished, and only stamped meat allowed

to be sold. Butchers argue that the handling and carting, entailed by the removal of the meat from the abattoir, tend to destroy the characters of home-killed meat, but this argument does not apply if suitable carts are used in which the meat is suspended by hooks from the roof.

The buildings of a public abattoir should include lairs for animals about to be slaughtered, separate places for such as are unsound, separate slaughter-houses for the different kinds of animals, cold storage for meat, buildings for the treatment and disposal of the offal and diseased parts, stables and sheds for horses and vehicles and the drivers' dogs, and a market-room with restaurant. There must be an ample water-supply, and the means of making ice should be provided.

Fish.

Though many parasites attack fish, the encysted form of the tape-worm called *Bothriocephalus latus*, which is sometimes found in the pike or turbot, is the only one which is known to be harmful.

Oysters and mussels have been known to produce poisonous symptoms, and nettle-rash is a frequent consequence of the consumption of the latter. Both mussels and oysters, which have been fed in sewage-polluted water, have conveyed the infection of enteric fever.

Meat Extracts.

Many meat extracts are now upon the market, the tendency being for the public to overestimate their food value. They consist of the extractives of meat, and not of the meat itself; and they act more as stimulants and regulators of digestion than as true foods capable of providing the necessary amount of nitrogenous material for the needs of the body.

MILK.

Milk is the natural food of all animals belonging to the Mammalia for a longer or shorter period following their birth. It therefore contains all the constituents of the standard diet, and these in the proportions most favourable for the growth and development of the young animal. In many of the milks secreted by the different kinds of animals, the fats, the nitrogenous substances, the salts, and the water, are found in proportions, as compared with the carbo-hydrates, largely exceeding those contained in the ordinary food of the adult animal. This is notably the case in man, the albuminates, the fats, and the salts being required in large quantities for the rapid growth of the body in infancy, whilst the water is essential for the quick formation of tissue and for the rapid elimination of waste products.

The varying proportions of the different solid constituents of milk as secreted by the human female, the cow, the ewe, the goat, and the mare, are shown in the table. The presumption is that the natural milk of one

AVERAGE PERCENTAGE COMPOSITION BY WEIGHT.

Constituents.	Cow.	Woman aged eighteen.	Woman aged thirty-three.	Mare.	Goat.	Ewe.
Specific gravity	1032·50	1034·50	1033·03	1036·12	1032·70	1039·30
Fat	3·76	3·20	2·99	1·76	5·80	11·28
Casein, albumin, etc.	3·50	2·39	2·51	3·58	4·20	8·83
Sugar	4·75	6·83	6·51	5·87	4·94	3·58
Ash	0·72	0·29	0·30	0·39	1·00	1·09
Water	87·27	87·29	87·69	88·40	84·06	75·22
Total ..	100·00	100·00	100·00	100·00	100·00	100·00

young animal is not suited for the nutrition of another animal of a different species. This is certainly true of the human infant, which thrives far better on its mother's milk, or the milk of a wet nurse, than on cow's milk—the almost universal food for hand-fed children. In cow's milk the casein is in far too large a proportion as compared with human milk ; the fat and salts are also in excess, whilst the milk-sugar is very deficient.

In the process of digestion, milk is curdled by admixture with the acid of the gastric juice ; the casein and fat separate as curd, whilst the sugar, the soluble albumins, and the salts, remain dissolved in the water as whey. The curd of human milk forms a loose flocculent mass, easy of digestion and assimilation ; whilst cow's milk clots in putty-like or wet cheese-like masses. The cow's milk curd is with difficulty digested ; it gives rise to dyspepsia, flatulence, and diarrhœa, and much of it may be passed unaltered in the fæces. Ass's and mare's milk approximate much more closely in composition to human milk, and give a loose, flocculent, and digestible curd like human milk. Goat's milk is too rich in fat and proteids, but it also gives the proper kind of curd in the human stomach.

For hand-fed infants under nine months of age, if cow's milk is used, it should be given diluted with water and with the addition of milk-sugar. The dense clotting may be, to a certain extent, prevented by the addition of some mucilaginous substance to the milk, such as pearl barley-water well boiled and strained, which has the mechanical effect of preventing the particles of casein coming too close together ; and the curd thus formed is looser and more easily attacked by the digestive juices.

Koumiss is a fermented drink prepared from mare's milk in Russia and Tartary, and in this country it is

now largely made from cow's milk. It is very easily digested and absorbed, and is a valuable food for invalids.

All the solid constituents of milk are dissolved in the water of the milk, with the exception of the fat, which exists as innumerable minute globules floating freely in the fluid.

Cow's Milk.

The average milk secretion of a healthy cow may be taken as 20 to 25 pints daily; but the quantity of milk and its richness in solid constituents depend largely upon breed in different cows, and in the same cow upon its age, the age of the calf, and the season of the year as influencing its food. As a general rule, it may be stated that cow's milk should have not less than 12·5 per cent. of total solids, of which 3·5 per cent. is fat, and 0·7 per cent. is salts, the specific gravity of the milk being 1031 or 1032, and the percentage of cream by volume not less than 10 per cent.

To make up the standard diet for an adult man, of 23 ounces of water-free food, about 9 pints of milk must be consumed. In such a diet, the albuminates, the fat, and the water would be far in excess of the requirements of the system. A prolonged course of milk diet—no other food being given—has been found exceedingly useful in certain cases of albuminuria and kidney disease. Skimmed milk only should be taken, and a portion of the casein should be separated by rennet (a preparation from the gastric mucous membrane of the calf). By this means the diet is deprived of much of its fat and albuminates; and the other constituents, being very assimilable, give the kidneys little work to do in elimination, whilst the water clears away disease pro-

ducts from the uriniferous tubules and promotes and restores healthy function.

Many persons, from constitutional idiosyncrasy or weak digestion, cannot digest milk. If the milk is first curdled by the addition of a few drops of acetic acid or a little rennet, and the curds and whey thus formed beaten up together, and a little salt and pepper added, a most digestible dish is prepared, by reason of the stomach being saved the operation of curdling which is the cause of the disagreement.

When milk is allowed to stand, some 60 or 70 per cent. of the cream rises to the top of the vessel in about six hours. A centrifugal apparatus is now largely used for the separation of cream; 90 to 95 per cent. of the fat is removed by this method. Skimmed milk generally contains about 1 per cent. of fat; whereas separated milk generally contains less than 0·3 per cent. More fat might be obtained by skimming if a longer period were allowed for the milk to stand; but after a time, depending upon the temperature, milk undergoes the lactic fermentation, and becomes markedly acid, the sugar being converted into lactic acid by the agency of a special bacterium, which grows and multiplies in the milk at suitable temperatures. The milk becomes curdled, and the whey separates from the curd. At a later stage the lactic acid is converted into butyric acid by means of another bacterium or bacillus; the milk at the same time becomes turbid, and putrefactive changes set in from the growth of *Bacterium termo* and other saprophytic organisms.

Milk may be sterilized, and thus preserved from fermentation and decomposition, by repeated boilings in vessels which are hermetically sealed at the boiling temperature. It is also preserved in a desiccated form as

a powder, the water being expelled by evaporation; or it is mixed with sugar and highly concentrated, being then sold as "condensed" milk. Many of the so-called condensed milks on the market are condensed skimmed or separated milks, *i.e.*, milk from which most of the fat has been abstracted prior to condensation. Such preparations are quite unsuited for infant feeding, and they have been well styled "starvation brands." It has lately become the custom, where milk is sent by railway from country farms to town retailers, to add a little salicylic acid, boroglyceride, formalin, or boracic acid to the milk as a preservative against fermentative changes in transit. Whatever antiseptic is used, it is consumed with the milk by the customer, and adds another danger to the already long catalogue attributable to milk.

This employment of agents, termed antiseptics, which will prevent the development of micro-organisms in food, is extensively practised. The antiseptics most commonly employed in different kinds of food are: Borax and boracic acid, salicylates, benzoates, formic aldehyde (used as "formalin," a 40 per cent. solution of formic aldehyde), sodium chloride, and vinegar; but saltpetre, chloride of ammonium, sulphate of calcium, alum, spirits of wine, sulphurous acid, bisulphite of lime, and sulphate of copper, have all been employed.

There is no doubt that the unrestricted use of these agents should be condemned; for although in the case of those most commonly employed their use has not been *proved* to cause any direct harm to consumers, it is rational to believe that the ignorant employment, even of such a substance as boric acid, may effect slight and indirect injury to health, and is capable of seriously interfering with digestion. Few of these agents enter normally into the constitution of the human body; and at least they

must be regarded as foreign bodies whose ingestion works no possible good, and which, not being foods, do not in any way make amends for the additional work of elimination which their presence demands. They sometimes, moreover, permit vendors or manufacturers to deal with stale or badly prepared food, to the prejudice of the more honest tradesman. If the adulteration is permitted, the vendor should at least be compelled to state the nature and amount of preservative employed.

Opinion is very divided as to the actual harm which results from the use of very small quantities of preservatives in food, but in the view of many authorities the use of such agents is unnecessary; and it is certain that even so rapidly decomposable a food as milk, when collected and stored with proper regard to cleanliness, and quickly chilled, can be sufficiently preserved by cold storage alone, even in the hottest weather, to meet all the requirements of its distribution and use.

There is at the present time a very copious literature dealing with the diseases and injurious effects attributable to the use of cow's milk. Forming, as it does, so large a proportion of the daily food of infants, young children, and invalids of all ages, and consumed, as it generally is, by all ages and all classes, in an uncooked state, the importance of the inquiries that have been made and of the facts that have been elicited can hardly be overestimated. The following considerations will be found of use in arriving at a proper understanding of the subject.

Milk has a remarkable power of absorbing gases and vapours, organic and inorganic. It is, besides, a fluid which, while possessing all the essential constituents of food, forms a most suitable cultivating medium for low forms of life, fungoid or bacterial. So that it is not too

much to assume that specific disease germs, which have gained access to the milk, may so grow and multiply as greatly to increase its power of infection as time elapses.

The chief sources of the infection of milk are dirt and water—dirt finding its way into the milk during the process of milking, and the water through the washing of the cans, or by wilful addition to the milk with the object of increasing its bulk.

Milk, as being derived from the living animal, must be also, to a great extent, a reflection of the animal's state of health. But we can go further than this, and say that milk is, for a certain period, derived from an animal in the puerperal condition consequent on parturition—a condition known to be liable to certain disorders, chiefly inflammatory, and particularly prone to take the infection of contagious disease.

Milk which has become acid from lactic fermentation is liable to cause sickness and diarrhœa in children ; and if *Oidium albicans* is present in the milk, it may attack the mouth and digestive tract of infants, causing thrush. Other fungi and moulds — penicillium, aspergillus, mucor, etc. (see p. 437)—when present, may cause severe gastric irritation. Similar symptoms have been produced by pus and fluids from inflamed udders and udder abscesses contaminating the milk.

There is now a large body of evidence to support the view that disease of the cow may be transmitted through the milk secretion to human beings.

In 1881 Mr. Ernest Hart completed tables with particulars of 50 epidemics of enteric fever, 15 of scarlet fever, and 6 of diphtheria — 4,800 cases of infectious disease in all—which had been traced to an infective or a supposed infective quality of the milk-supplies, and

since that date there have been numerous other milk epidemics recorded.

In the case of *enteric fever*, the most usual means by

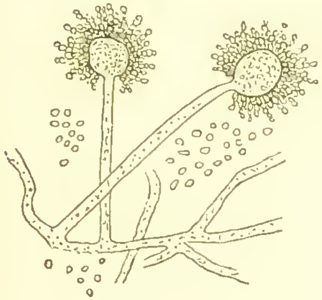

FIG. 56.

FIG. 57.

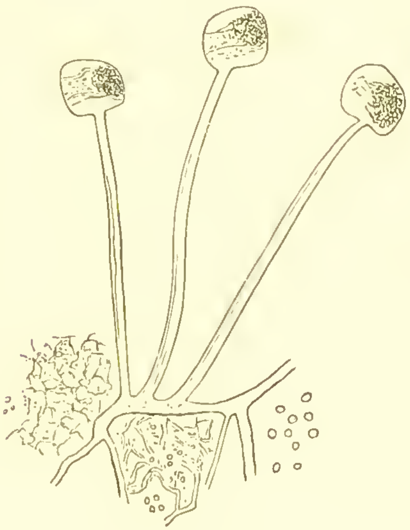

FIG. 58.

FIG. 56.—ASPERGILLUS GLAUCUS. (× about 150 diameters.)
FIG. 57.—PENICILLIUM GLAUCUM. (× about 200 diameters.)
FIG. 58.—MUCOR MUCEDO. (× about 80 diameters.)

which milk obtains its specifically infectious quality is the washing of the milkcans, or the intentional dilution of the milk, with water polluted by typhoid dejecta. In

other cases the milk has been found to be stored in rooms or dairies the air of which was subject to drain or sewer emanations. It is also possible, though improbable, that enteric fever is a disease of cattle communicable to man through the milk secretion, or by means of pollution of the milk by the alvine discharges through careless milking.

In those epidemics of *scarlet fever* which have been traced to milk, it has been usual to find that the milk was infected through human agency by a previous case of the disease at farm or dairy. The cows were milked by a person who was attending on a scarlet fever patient, who had the disease amongst his family—possibly in an unrecognised form, as sore throat without rash—or who was himself suffering from it in a mild or disguised form. Occasionally the milk appears to derive its infective quality from being kept in a room in which clothes or refuse matters from the sick are lying.

But besides such easily understood methods, the history of the Hendon and Wimbledon outbreaks appears to show that cows are liable to a disease identical with or very closely resembling human scarlet fever, and that the milk from animals so suffering might prove to be the cause of epidemic outbursts of the disease amongst those who consumed it. Dr. Klein isolated an organism—a streptococcus—from the udder lesions (ulcers) on the Hendon cows, which he believes to be the true pathogenic organism. A streptococcus has also been found in the diseased organs and tissues of human scarlatinal cases.

Subcultures of this organism obtained from human scarlatinal cases, when inoculated into recently calved cows, are said to produce the characteristic ulcers on the teats, along with other manifestations of the Hendon

cow disease; and calves fed on these subcultures obtain the same disease. This matter has been, however, and still is, the subject of much controversy. The opponents of the views of Dr. Klein, and of Mr. Power, who investigated the Hendon outbreak, hold that a possible human source of the disease at Hendon was not absolutely excluded, and assert that other cows which had the Hendon disease did not give rise to any scarlet fever outbreak.

In a large percentage of the milk epidemics of *diphtheria*, it has not been possible to trace the source from which the milk derived its infective quality. This is not to be wondered at, for, in the first place, our knowledge is not yet sufficiently definite to enable us to exclude diphtheria from the class of diseases which are not necesarily dependent on an immediately pre-existing case, and which appear to arise at times from ordinary insanitary conditions; and, in the second place, slight cases of diphtheria are very difficult to trace, the diphtheritic character of a sore throat not being always recognisable even to a medical attendant. There is but little evidence tending to show that diphtheria may be a cow disease transmissible to human beings. Calves have been known to suffer from a throat affection presenting post-mortem appearances very similar to those found in human diphtheria. But this disease of calves, even if it were more general than it is, would not account for diphtheria appearing amongst the customers of those establishments—the great majority in or near large towns—where the calves are sent away as soon as born, and the cows come after three or four days into regular milking. The question as to whether garget or mammitis in cows is capable of producing diphtheria in the consumers of milk taken from gargety udders may be answered in the negative.

Stall-fed dairy cows in towns are very susceptible to *tubercle.* Veterinary authorities have stated that at least 25 per cent. of all dairy cows kept in towns are the subjects of this malady. These animals are stalled day and night in stables often uncleanly and badly ventilated, and they are perpetually being drained of large quantities of milk. Prolonged lactation in the human female is well known to be a frequent precursor of phthisis; and it is not wonderful that under such circumstances, and with the additional factors of confinement, want of exercise, and bad air, cows should succumb to a malady to which they are in a high degree susceptible. It often happens that the best-bred animals, which are usually the best milkers, are those which are most affected. In the early stages the symptoms of the disease are ill defined, the health of the animal is not much interfered with, and the milk secretion is as abundant as ever. Nutrition is not interfered with until the disease is far advanced, and even then the amount of milk yielded, although poor in quality, may not be diminished, and the dairy farmer continues to keep the animal in stock.

So far as at present known, the milk of tuberculous cows is free from tubercle bacilli, unless there has been —as is sometimes the case—a deposition of tubercles in the glands of the udder. In every town dairy of any size there will probably be tubercular cows, some of them most likely with tubercular udders; and as it is the common custom of dairymen to mix together the milk yielded by different cows, it is not too much to assume that tubercle bacilli may be widely distributed in the milk-supply. As a matter of fact, the bacilli have been found by many observers in from 10 to 20 per cent. of the dairy samples examined by them.

The bacilli of bovine tuberculosis are identical—accord-

ing to all bacteriological methods at present known—with those found in tubercular formations in the human organs, although the disease presents anatomical differences in man and cattle. But these differences are probably due to differences of soil in the human and bovine tissues, the bacilli engrafting themselves in those tissues which present conditions most favourable to their growth and development.

It has been shown that the milk of tuberculous cows containing tubercle bacilli, when given as food, produces tuberculosis in rabbits, guinea-pigs, and dogs. The absence of direct evidence of the transmissibility of the bovine disease to man is due to the great difficulties surrounding such determinations, and also to the want of observation and of properly recorded data. A strong confirmation of the view that bovine tuberculosis is transmissible, at least to young children, is contained in the fact that the mortality of children under five years of age from primary tubercular ulceration of the intestines, and from tuberculosis of the peritoneum and mesenteric glands (tabes mesenterica), is very high. The mortality of children under five from tubercular peritonitis and tabes mesenterica for the period 1881 to 1890 approaches closely the mortality from measles for the same period, and is some sixteen times as great as the mortality figure from these diseases in any of the five year age-periods in later life. The extreme incidence of primary tubercular disease of the abdominal lymphatic system on young children is at once seen from these figures. There can be little doubt that the tubercular virus in these cases is introduced into the body with the food, and that the virus is absorbed through some part of the digestive tract. In the matter of dietary there is one great distinguishing feature between this age-period

and all others: under five years of age, unboiled milk forms the staple food of children.

The sanitary improvements of the last forty years have reduced the death rate from tuberculosis of the lungs by 45 per cent. During the same period the death-rate from tuberculosis of the bowels among infants under one year old has increased by 27 per cent., this increase being coincident with an increase in the proportion of infants reared on the bottle, instead of on their natural nutriment.

Foot and mouth disease, or *epizoötic eczema*, is a contagious disease, characterized, in cows, by an eruption of small vesicles on the lining membrane of the mouth and the interdigital spaces of the feet; not infrequently the vesicles appear on the udders and teats. In the majority of cases the milk secretion is diminished as the disease progresses, and may become entirely suspended. The fever runs its course in from eight to fifteen days. The contagium exists in its most concentrated form in the lymph or serum of the vesicles (those on the teats are liable to be ruptured in milking) and in the saliva; but it also exists in the secretions and blood of diseased animals, and it possesses considerable vitality.

Numerous outbreaks among human beings of a peculiar illness have been traced to the use of milk from cows with this disease. The symptoms were slight fever, vesicular eruptions on the throat and lips, swelling of the tongue, salivation, fœtor of breath, and marked swelling of the lymphatic glands of the neck. It is probable that the transmission of the disease is most certain in those cases where there are vesicles on the cow's teats, which are sure to be ruptured in milking, the virus thus obtaining direct access to the milk.

In the case of cows suffering from *cattle plague* and

anthrax, the milk secretion is suspended at a very early stage, whilst in *contagious pleuro-pneumonia* and *rabies* there is no evidence of any ill effects. In *cow-pox* the milk secretion is said to be rapidly diminished or suppressed.

A milk epidemic is characterized by the suddenness with which it makes its appearance, the sufferers being for the most part attacked at about the same time. The infected houses will be found to have been supplied, almost without exception, by the particular milk-vendor whose supply is at fault; but it will occasionally happen that infected houses are discovered to which milk has been supplied from a different vendor, this circumstance being often due to the fact that the vendors on their rounds very commonly buy small quantities of milk from each other. Sometimes valuable corroborative testimony implicating the milk is forthcoming in the circumstance that some of those in the infected households, who have consumed no unboiled milk, have escaped; and that households supplied from the implicated dairy, but in which no unboiled milk is consumed at all, have entirely escaped.

Until cowsheds and dairies are placed under rigorous sanitary control, and until cow diseases are better understood and recognised, the only safeguard against the spread of disease through milk is to boil it. Exposure to the heat of boiling water for five minutes destroys the life and action of every variety of specific disease virus, and practically sterilizes the milk. The sterilization—the destruction of all living organisms—is of especial importance where infants are fed on cow's milk. Under natural conditions the mother's milk, as sucked in by the infant, is free from all organic life; but where cow's milk is substituted, living germs are introduced into the stomach, which may at this tender age be unable to cope

with them, and ill-health and disease ensue. The act of boiling produces but little alteration in the nutritive properties of the milk, and its value as a food is not seriously affected thereby.

A large proportion of the milk retailed in London has had some of its cream separated; whilst the fraudulent addition of water is exceedingly common in districts where the Adulteration Acts are not enforced. Annatto, turmeric, and yellow coal-tar colours have been employed to give a rich yellow colour to a naturally poor or watered milk.

Butter.

When the cream of milk is churned, *i.e.*, violently agitated in a suitable apparatus, the fat globules coalesce, entangling in their meshes some casein and serum. The butter so formed is then pressed to squeeze out some of the moisture, and salt added to preserve it. The percentage proportions of the constituents of butter are approximately as follows:

Fat	83·5
Curd	1
Ash	1·5
Milk-sugar	1
Water	13

The fat of butter consists of a mixture of the glycerides of the fatty acids—palmitic, stearic, and oleic—not soluble in water; and also of the glycerides of certain soluble and volatile fatty acids, principally butyric, with small quantities of caproic, caprylic, and capric acids. It is the association of about 7·8 per cent. of the triglycerides of these volatile acids with the glycerides of the insoluble acids which gives to butter-fat its peculiar and distinctive characters (Wynter Blyth).

Margarine, *oleo-margarine*, or *butterine*, is manufactured chiefly from beef and mutton fat—a mixture of stearin,

margarine, and olein. The beef-fat is first finely minced and heated in tanks to about 39° C. The fat melts, and the water and débris sink to the bottom. The melted fat is run off as a clear yellow oil, and kept at a temperature of about 30° C. The stearin to a certain extent solidifies at this temperature, whilst the oleo-margarine is separated as a liquid, from which much of the stearin has been removed; for oleo-margarine solidifies at a much lower temperature than stearin. The oleo-margarine is then filtered, pressed, churned up with milk to give it the flavour of butter, coloured with annatto, and cooled with ice, when it is ready for sale.

The average percentage composition of dry margarine fat is as follows (Wynter Blyth):

Palmitin	22·3
Stearin	46·9
Olein	30·4
Butyrin, caproin, and caprylin ..	0·4

The great distinction between butter-fat and margarine-fat lies in the fact that the butter-fat contains nearly 8 per cent. of the volatile fats, whilst the margarine-fat has barely ½ per cent. In the analysis of these substances this difference is made use of. The same antiseptic and colouring agents are employed in butter as in milk.

Cheese.

In the manufacture of cheese, casein and most of the milk-fat are precipitated from milk by rennet at a suitable temperature. The curds are then pressed, to squeeze out the whey and reduce the mass to a proper shape. In the process of decay the fat increases at the expense of the casein, and numerous alkaloidal substances, extractives, and aromatic acids are produced, which give

a decayed cheese its aroma. These bodies are harmless, but occasionally a poisonous ptomaïne called "tyro-toxicon" appears to be produced. This substance has also been discovered in milk, cream, butter, and cheap ice-creams, and in milk stored during hot weather. The symptoms produced by tyro-toxicon are allied to those of atropine-poisoning. Various kinds of parasites grow in decaying cheeses, but they do not seem ordinarily to produce any harmful effects. The more common are: *Aspergillus glaucus* (causing blue or green mould), *Sporendonema casei* (causing red mould), and the cheese maggots (*Piophila casei*).

Wheat Flour and Bread.

Wheat flour contains about 15 per cent. of water, 8 to 12 per cent. of gluten (vegetable albumin), and 60 to 70 per cent. of starch, sugar, and dextrine. It is very deficient in salts and fat. In the finest flour nearly all the outer envelopes of the wheat grain are separated. This separation of the bran, whilst it renders the flour fine in texture and white in colour, deprives it of much nutritious matter, for bran contains 15 per cent. of nitrogenous substances, 3·5 per cent. of fat, and 5·7 per cent. of salts. On the other hand, most of this nutritious matter is in a form difficult of digestion and irritating to the bowels, for the outer envelopes of the wheat grain are hard and silicious. Bread made from wholemeal flour is coming largely into favour. Where it can be tolerated its use may be advantageous, as it promotes evacuation of the bowels, and is more nutritious than ordinary white bread. It is certainly deserving of trial by the working classes, whose diet is often deficient in salts, fat, and nitrogen; and with the modern methods of very fine grinding its irritant properties are reduced to a minimum.

Bread is made by mixing water, yeast, and a little salt with wheat flour until a consistent dough is formed, which is allowed to rise before a hot fire, and then placed in a baking oven. By the action of the yeast at a suitable temperature, some of the starch is changed into sugar, and the sugar splits up into alcohol and carbonic acid gas. The coherent nature of the gluten prevents the escape of the carbonic acid, which forms for itself little cells in the substance of the loaf, and causes the spongy structure characteristic of well-made bread. The alcohol escapes into the air. It is important not to let the fermentative process go too far, or lactic and butyric acids may be formed, which cause the bread to be sour. Alum has the property of arresting this change, and of imparting a fine white colour to bread. Hence its frequent use in baking-powders. The loaf is then put into the oven and baked. It appears, from experiments lately conducted by Drs. Waldo and Walsh, that the temperature of the interior of a loaf in a baker's oven is not sufficiently high to destroy all microbes. The process of baking, therefore, does not sterilize the loaf.

Aerated bread is now extensively used. In this system CO_2 gas is prepared and forced through the dough under pressure. Its great advantage lies in the fact that there is no fermentation as in ordinary bread-making, and no danger of sourness and acidity being produced. There is besides no loss of starch, and no yeast is left in the bread to cause fermentative changes in the stomach, giving rise to acidity, heartburn, and flatulence. On the other hand, the yeast fermentation is supposed to render the bread more easily attacked by the digestive juices—in other words, more digestible. Baking-powders are occasionally used to disengage CO_2 gas, and cause dough to rise. They usually consist of sodium carbonate and

some acid such as citric or tartaric, the acid and alkali being brought together for use.

FIG. 59.—PUCCINIA GRAMINIS. (× about 200.)

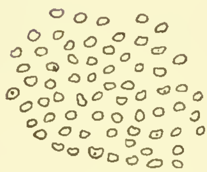

FIG. 60.—SMUT SPORES: UREDO SEGETUM. (× about 200.)

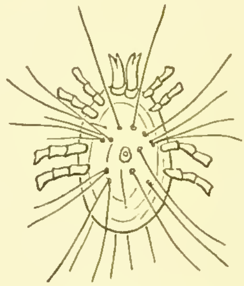

FIG. 61.—ACARUS FARINÆ. (× about 40.)

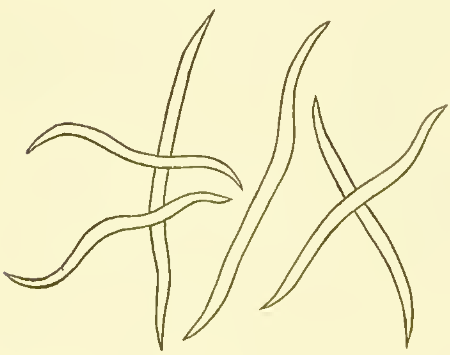

FIG. 62.—VIBRIONES TRITICI. (× about 40.)

FIG. 63.—WEEVIL. (× about 40.)

Under the microscope (Fig. 74) wheat flour is seen to consist of round or oval starch grains, of very various

sizes. The smallest are mere points, whilst the larger ones may reach to $\frac{1}{1000}$ inch in diameter or more. Intermediate sizes are very often absent. The hilum and concentric lines of the starch grains are barely visible, if at all. Portions of the outer envelopes of the wheat grain may be detected in the coarser and more branny flours.

Wheat grains are subject to attack by certain parasites, viz. (Figs. 59 to 62), smut (*Uredo segetum*) and bunt (*Uredo fœtida*), the latter being the commonest; rust or *Puccinia*

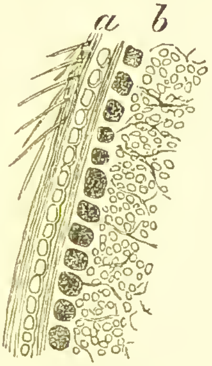

FIG. 64.—SECTION OF WHEAT GRAIN: OUTER COAT. (× about 50.) *a*, Girdle cells; *b*, cerealin cells.

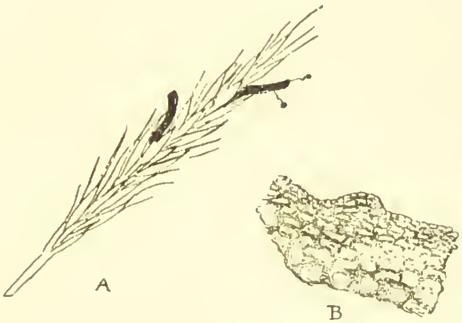

FIG. 65.—A, Ear of Rye with ergot—the latter shown as germinating and producing *Claviceps purpurea*; B, a slice of ergot. (× about 250.)

graminis, which attacks the stem and leaf; and ergot (*Oïdium abortifaciens*), which, however, is more often a disease of rye. Amongst the numerous animal destroyers of wheat are: *Vibrio tritici*, or ear-cockle, which destroys the grain and fills it with a cotton-like substance; *Acarus farinæ*; and the weevil, or *Calandra granaria* (Fig. 63), a little insect—visible to the naked eye—which eats the core out of the grain, leaving only the shell. *Lolium*

temulentum, or darnel seeds, occasionally find their way into flour, and have given rise to symptoms of narcotic poisoning among some of those who consumed the bread made from such flour.

Other fungi may likewise be recognised by means of the microscope in the flour made from blighted and diseased corn ; and flour and bread, when badly stored and allowed to become damp, become the seat of growth of moulds and fungi such as *Mucor mucedo*, *Penicillium*, and *Aspergillus* (see p. 437). All these growths are apt to produce dyspepsia and diarrhœa, whilst the prolonged consumption of ergoted bread may give rise to the symptoms of ergotism, viz., painful cramps in the limbs and gangrene of the extremities. Ergot may be detected by the herring-like smell of propylamine which is produced when liquor potassæ is added to ergoted flour.

With wheat at its present low price, adulteration is very little practised. Alumina is normally present to a very slight extent in flour and bread (equivalent to 6 to 10 grains of alum in a 4-pound loaf); when alum is added in any quantity, its presence may be detected by pouring a fresh infusion of logwood, made with distilled water, over the flour or bread. The colour of the logwood changes to a lavender or violet-gray in the presence of alum. There can be little doubt that alumed bread tends to produce dyspepsia and constipation, and it permits of an inferior flour being sold as a good one.

The adulteration of wheat flour with other grains, such as barley, potato, beans, peas, maize, oats, rye, and rice, is now but little resorted to ; and the addition of mineral matter (calcium sulphate and carbonate) is now seldom, if ever, practised.

The nitrogenous substances in these grains have little or no adhesive properties like wheat gluten, so that

bread cannot be made from them, or only bread of an inferior quality.

The nutrition values of some of these cereals will be seen from the following table :

	Wheat (winter-sown).	Barley.	Oats.	Maize.	Rye.	Rice.
Starch*	63·71	63·51	49·78	64·66	61·87	77·66
Nitrogenous matter (*i.e.*, albumin, cerealin, etc.) ..	15·53	11·46	14·67	14·27	14·87	9·34
Cellulose ..	3·03	7·28	13·53	1·86	3·23	traces
Sugar†	2·57	1·34	2·36	1·94	4·30	0·38
Fat	1·48	1·03	5·14	3·58	1·43	0·19
Mineral matter	1·60	2·32	2·66	1·35	1·85	0·28
Moisture ..	12·08	13·06	11·86	12·34	12·45	12·15
Total ..	100·00	100·00	100·00	100·00	100·00	100·00

It will be seen that barley is—compared with wheat—poor in nitrogenous matter and sugar, but rich in cellulose and mineral matter ; that oats are exceptionally rich in cellulose and fat, possess a high amount of mineral matter, but are relatively poor in starch ; that maize possesses a high amount of fat, but the cellulose is low ; that rye is exceptionally rich in sugar, and in other respects closely approximates to wheat ; and that rice is rich in starch, but poor in everything else.

Barleymeal, oatmeal, peas, lentils, and maize or Indian corn, are all most nutritious and fattening, and very cheap. They are easily made into most nourishing porridges, soups, and puddings, with a little milk, and form very valuable—though greatly neglected—foods for

* The starch includes from 1 to 1·5 per cent. of dextrine, and, together with cellulose and sugar, comprises the carbo-hydrates of the cereals.

† The saccharine body is allied to cane-sugar in its reactions.

people of small incomes. Starchy foods must be carefully cooked to render them digestible. By boiling or otherwise cooking, the cellulose coats of the starch

FIG. 66.—POTATO. (× 200.)

FIG. 67.—ARROWROOT. (× 200.)

FIG. 68.—MAIZE (× 200.)

FIG. 69.—RICE. (× 200.)

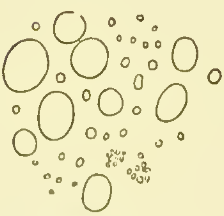

FIG. 70.—BARLEY. (× 200.)

FIG. 71.—PEA. (× 200.)

granule are ruptured, and the saliva and pancreatic juice then have ready access to the granulose—the inner contents of the granule.

Barley.—The starch grains are almost indistinguish-

able from wheat. Barley is very nutritious, and the ash is rich in iron and phosphates.

Rye.—The starch grains are like those of wheat, but

FIG. 72.—BEAN. (× 200.)

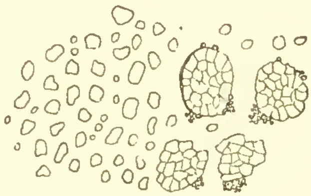

FIG. 73.—OATMEAL. (× 200.)

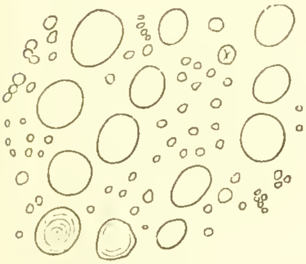

FIG. 74.—WHEAT. (× 200.)

FIG. 75.—SAGO. (× 200.)

FIG. 76.—TAPIOCA. (× 200.)

many have a peculiar rayed hilum. Rye can be made into bread, which is very acid and dark-coloured, and liable to produce diarrhœa in those unaccustomed to it.

Oatmeal.—The starch grains are small and angular, and tend to cohere into rounded masses. It is most nutritious and somewhat laxative. When badly prepared, oatmeal may contain hairs and husks, which are liable to form intestinal concretions.

Maize.—The starch grains are small, compressed, and faceted. Pellagra, or *Elephantiasis Italica*, is a constitutional disease operating destructively on the integument. It is most prevalent among those living under the adverse conditions of dirt and poverty so rife in Italy. That the consumption of diseased maize, to the exclusion of other diet, is the main factor in producing epidemics of the disease is proved by the circumstance that in the Lombardo-Venetian territory, where this is the chief food of the agricultural labourer, the disease is most in evidence.

Peas and Beans.—Pea starch grains are more or less oval, and many of them have a central longitudinal cleft extending nearly the whole length of the grain. Bean starch cells are somewhat larger and more flattened, and the longitudinal cleft is crossed by transverse fissures. Peas and beans contain a large amount of proteid substance called legumin (hence the name of Leguminosæ applied to these vegetables), also sulphur and phosphorus. They are highly nutritious, but somewhat indigestible, and are apt to give rise to flatus from the formation of sulphuretted hydrogen.

Rice.—The starch grains are very minute, angular, and faceted ; in shape like maize starch cells, but very much smaller. Rice is poor in everything but starch, which is, however, extremely digestible when cooked.

Arrowroot.—There are many different kinds of arrowroot, obtained from various countries. As a rule, the starch grains are oval or pyriform in shape, of large size,

and with the hilum as a slight cleft or cross at the larger end of the grain. The concentric lines are very well marked.

Sago and Tapioca.—The starch grains of sago are large, irregular in shape, with ill-defined concentric lines. Those of tapioca resemble sago, but are considerably smaller.

Potato.—The starch grains of potato are very characteristic. Many of them are large and pyriform in shape, the hilum being at the smaller end, and the concentric lines are very well marked. Potatoes are very deficient in proteids and fats, but the starch is most digestible when properly cooked; and they are most valuable antiscorbutics, for they contain large quantities of the salts of the vegetable acids—malates, tartrates, and citrates. The juice of the potato is acid. Potatoes are better cooked by steaming in their skins than by boiling when peeled; for by the first method there is no loss of the salts to the water used for boiling, as occurs in the second method.

In the case of all vegetables, and, in fact, in all cooking processes, soft water is far better than hard water, which coats the substances with a layer of chalk deposit, and prevents the penetration of heat to the interior.

BEVERAGES.

Coffee.

Coffee berries contain fat, legumin, sugar, dextrine, vegetable acids, and mineral salts; also an aromatic oil, an alkaloid—caffein (about 0·8 per cent.)—and an astringent—caffeo-tannic acid. When the berry is roasted, it swells from the formation of gases, the sugar is changed into caramel, and the aroma is developed. The roasted

coffee is made into a beverage by infusion with nearly boiling water. If the water is used at a boiling temperature some of the aroma is lost.

The coffee infusion acts as a stimulus to the nervous system; it increases the frequency of the heart's action, the urinary excretion, and the action of the skin, and is said to increase the evolution of carbonic acid from the lungs. It has considerable effect in removing the sensation of fatigue. It is valuable as a beverage for men

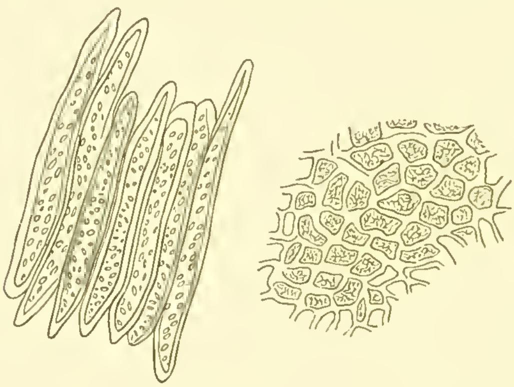

FIG. 77.—COFFEE: CELLS OF TESTA AND CELLULAR STRUCTURE. (× about 200.)

undergoing exertion both in hot and cold climates, from its stimulant and invigorating qualities. The heat of the infusion is useful in cold climates, whilst the increased action of the skin produces a cooling effect in hot climates.

The principal adulterant of coffee is chicory. Occasionally starches, such as arrowroot and potato flour, are fraudulently added. Under the microscope, diligent search should be made for the long oval cells of the testa of the berry, with their irregular cross-markings (Fig. 77); and fragments of the internal structure of the berry may be seen, consisting of an irregular network of fibres forming a cellular structure, in which are contained dark

angular masses and oil globules. All these structures are better seen before the berry is roasted and ground. Chicory is revealed by the presence of fragments of much coarser areolar tissue, and by the long dotted ducts, which are quite characteristic (Fig. 78).

Roasted coffee floats for a considerable time in water, owing to the gases that are developed in roasting, and to the quantity of fat it contains; whilst roasted chicory rapidly sinks. Chicory contains no aromatic oil nor caffein like coffee, but it has much sugar in its composi-

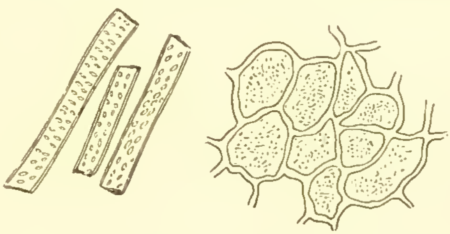

FIG. 78.—CHICORY: DOTTED DUCTS AND CELLULAR STRUCTURE. (× about 200.)

tion. When mixed with coffee it serves to sweeten it, and causes a darker-coloured infusion than pure coffee gives. Other more rare adulterants of coffee are other starches (such as potato and sago), and caramel or burnt sugar.

TEA.

Dried tea-leaves contain albumin, extractives, dextrine, and mineral salts, also tannin (about 13 per cent.), an aromatic oil, and an alkaloid—thein (3 per cent.). Green tea contains more tannic acid and ethereal oils than black tea, and is prepared from younger leaves, but the thein appears to be generally less in amount. The difference between black and green teas is entirely due to their mode of preparation; they are both derived from

the same plant. Formerly tea was exported almost exclusively from China, but now Indian and Ceylon teas have come largely into the market.

Tea should be made with boiling water, but it should not be allowed to stand for more than five minutes, the infusion being then poured into another vessel. If this is not done, so much tannin is extracted as to cause the infusion to be bitter and astringent, and most unwholesome. If soft water is used, a smaller quantity of tea is necessary than with hard water, as the soft water extracts more from the leaves than hard. Dextrine, glucose, tannin, thein, the volatile oil, and a small quantity of the albumin pass into the infusion. Tea should not be taken with or shortly after meals, as the tannin tends to coagulate the albumins of the food undergoing the process of digestion.

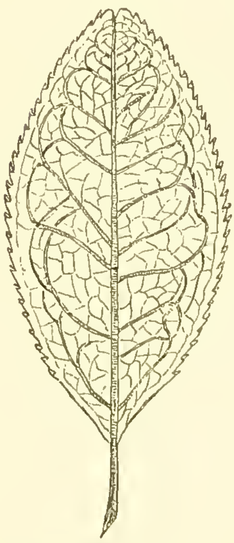

FIG. 79.—TEA-LEAF.

The action of tea on the system is similar to that of coffee. It is, therefore, valuable as a nervous stimulant and restorative in fatigued conditions of the body. The abuse of tea leads to weakened digestion, constipation from the astringent properties of the tannin, and nervous depression leading to insomnia and trembling—the effects of the volatile oil and thein.

The structure of the tea-leaf is characteristic, and is best seen when the leaf is young and green. It is oval in shape (Fig. 79), with a serrated border, each serration being spine-mounted, and the serrations terminating a little before the point of attachment of the stalk; the primary veins run out alternately from the midrib, and

turn towards the point of the leaf, but without reaching the border, the venation being looped; the apex of the leaf is notched. Adulteration with foreign leaves is now little practised; but used leaves may be dried, mixed with gum and rolled, and sold as sound tea. Green tea used to be coloured or faced with indigo, Prussian blue, and other mineral substances.

Cocoa.

Cocoa is a food as well as a beverage, and is much less astringent than tea or coffee. Cocoa nibs contain nearly 50 per cent. of oil (cocoa butter), proteids about 15 per cent., and theobromin—allied to thein and caffein

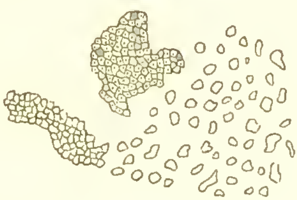

Fig. 80.—Cocoa Starch Cells. (× about 200.)

—0·5 to 1·7 per cent. The ash is rich in phosphate of potash. For people of weak digestion, some of the fat of the cocoa should be removed in its preparation.

Cocoa is generally adulterated with sugar and the cheaper starches, in order to disguise the large amount of fat and to render it more palatable. Some of the homœopathic cocoas contain hardly any cocoa at all. The starch grains of cocoa are very small, and are often seen massed into the intercellular spaces of the structure of the nib (Fig. 80).

Mineral Waters.

These are either derived from natural springs, the water of which contains gases (usually CO_2) or mineral

salts in solution (salts of potassium, sodium, magnesium or lithium), or they are manufactured by impregnating ordinary river, spring, or well water, with CO_2 gas, and dissolving in it small quantities of the mineral salts usually found in natural waters. Both kinds of water have come very largely into use in recent years. Besides the stimulant effect upon the digestive organs of the contained CO_2 and the dietetic value of the mineral salts, these waters serve a useful purpose in providing a pure beverage for consumption in cases where there may be hesitation to drink the ordinary water provided for domestic purposes, on the ground of its possibly being tainted with impure matters derived from drains, cess-pools, or other sources. Care should be taken, however, to choose a mineral water which does not contain an excess of common salt, producing thirst, or an excess of alkaline salts, which act as depressants on the nervous system. Travellers both at home and abroad usually show a wise discretion in their preference for mineral waters to the ordinary water of the establishments in which they are staying or seeking refreshment. Too much reliance, however, should not be placed on the purity of the artificial waters, as in more than one instance it has come to our knowledge that certain manufacturers have obtained their waters from grossly polluted sources.

There is one other danger in the use of the artificially aerated waters that requires mention. They very commonly exhibit traces, and often very decided traces, of lead. This metal is dissolved from lead pipes or leaden apparatus used in the manufacture of the CO_2, and the water charged with this gas holds the lead in solution. On driving off the CO_2 by boiling, the lead is usually deposited with the sediment of the alkalies, which are

also held in solution by the gas. Another possible source of the metal is the silicate of lead which enters into the composition of the glass bottles in which such waters are stored; and traces of lead may be found in bottles which have been scoured with lead shot, and subsequently not been properly washed out. The habitual use of these waters containing traces of lead would undoubtedly in time lead to the development of symptoms of lead-poisoning, the source of which would in all probability be overlooked.

Fermented Liquors.

A solution of grape-sugar when subjected to the action of the yeast plant (*Saccharomyces cerevisiæ*) at a temperature

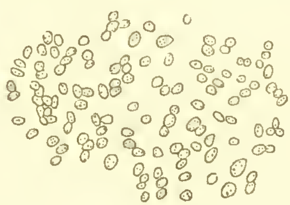

Fig. 81.—Torula Cerevisiæ: Yeast Plant. (× about 200.)

of from 20° C. to 30° C., is mainly split up into alcohol and carbonic acid.

$$C_6H_{12}O_6 = 2C_2H_6O + 2CO_2.$$

The yeast plant is composed of minute organized cells, oval in shape, and with granular protoplasm (Fig. 81). In the presence of saccharine fluids at a suitable temperature, the cells undergo enormous multiplication by the process of budding, and the alcoholic fermentation ensues. Under the microscope, the cells which are budding may be seen as one large cell united to one or two smaller cells, end to end; or groups of several budding cells are attached together. The CO_2 escapes as gas from the

fermenting liquor, whilst the alcohol remains dissolved in the solution.

The fermented drinks may be considered under the heads of spirits, wines, and beers.

Spirits.—Brandy is manufactured by the distillation of wine. It contains from 50 to 60 per cent. of alcohol, the remainder of the liquid being water, in which are held various aromatic ethers (acetic, œnanthic, butyric, and valerianic) and traces of other bodies. Its specific gravity is about 0·930 at 62° F. Rum is distilled from fermented molasses.

Whisky is made by distillation of malted grain. When new, it contains amylic alcohol or fusel-oil, a substance which, when present in any quantity, produces rapid intoxication, followed by intense headache and depression. The percentage of alcohol in whisky is much the same as in brandy. Gin is weaker in alcohol; it contains oil of juniper, and is sweetened with various aromatic substances. Absinthe is a liqueur flavoured with various essential oils, and contains oil of wormwood, a powerful poison to the nervous system.

Wines.—What are known as the lighter wines—the bordeaux, burgundies, Rhine wines, champagnes, and moselles—contain usually less than 10 or 15 per cent. of alcohol by volume. The stronger wines—port, sherry, and madeira—contain from 15 to 25 per cent. of spirit. Besides alcohol, wines contain various aromatic compound ethers (œnanthic, citric, malic, racemic, butyric, caprylic, pelargonic, etc.) which impart the bouquet, albuminous and colouring matters, sugar, free organic acids, and the acid salts of the vegetable acid series, including tannic acid (which is largest in amount in new port wines) and mineral salts, chiefly those of potassium.

Wines are manufactured from the fermented juice of the grape. Cheap wines are largely made from other fruits, and even grape-juice wine is subject to various fortifications and adulterations to fit it for different markets. Home-made wines and cider are occasionally manufactured or stored in earthenware vessels, coated inside with a litharge glaze, which readily gives up large quantities of lead to such acid liquids, and is thus productive of lead-poisoning. If earthenware vessels are used, they should be coated with a hard salt glaze. When wine is kept long in cask or bottle, there is a deposit of the colouring matter and tannic acid, and some of the sugar disappears. If air is not absolutely excluded, the acetous fermentation is liable to be set up from the entrance of the ferment (*Mycoderma aceti*), which transforms alcohol into acetic acid (C_2H_6O becomes $C_2H_4O_2$), and the wine is soured. The more common adulterants used are sugar, various ethers, logwood, alum, and sulphate of lime. The latter improves the colour of cheap wines, and the addition is known as the "plastering" of wine. The practice is injurious, and by giving rise to the formation of potassium sulphate it induces a purgative effect upon consumers.

Beers.—These beverages were formerly made from malt and hops only; now they can be legally made from starch and sugar and various vegetable bitters. In the process of brewing, malted barley is subjected to successive infusions to convert the starch into grape-sugar, and this liquid—the "wort"—is then fermented, after the addition of yeast, in large open vats at a temperature of 15° C. to 18° C. The yeast floats on the surface, and is removed by skimming. Hops or other bitters are then added. The percentage of alcohol in beer varies from 3 per cent. in the lighter to 6 or 7 per

cent. in the heavy beers. There are also contained in beer, malt extract (dextrine, sugar, lupulite, etc.), 4 to 15 per cent., free organic acids, traces of albuminous matters, and salts.

Considered as articles of diet, wine and beer will produce effects which may be partly ascribed to the action of alcohol on the system, and partly to the other constituents of which they are composed.

Leaving out of consideration for the moment the effects of the alcohol, it will be seen that wine and beer possess some of the properties of a food. They contain sugar and starchy matters, mineral salts rich in potash and phosphates, and a considerable amount of the vegetable acids and their salts, which are so valuable as antiscorbutics. The compound aromatic ethers in wine may also act as aids to digestion, by promoting the flow of the pancreatic and intestinal juices; and the bitters of beer act as stomachic tonics. Little can be said against the use of beer and wine in strict moderation; but taken habitually in excess, they lead to the storage up of superfluous fat in the tissues, and they interfere with the proper elimination of effete matters; imperfect oxidation leads to an excessive formation of uric acid, and a plethoric and gouty habit are produced, eventually tending to palpable disease. These effects are, doubtless, in part due to the excess of alcohol taken into the system, but not entirely. Lessened metamorphosis has a considerable share in their production.

Effects of Alcohol.

Alcohol when taken into the body is rapidly absorbed unchanged into the blood. Taken in excess, it speedily commences to pass out of the body in an unaltered

condition. The principal channel of elimination is the lungs and breath, but small portions are got rid of by the skin, the urine, and the bowels. The greater portion, however, of the alcohol (98 per cent.) is destroyed in the body. In fact, when taken in small (not excessive) quantities, alcohol acts as a food, supplying heat and energy by its oxidation in a similar manner to the fats and carbohydrates.

After full doses of alcohol given to a healthy man or animal, the following effects have been noted: 1. The vessels of the stomach are dilated, and the flow of gastric juice augmented. 2. The force and frequency of action of the heart are increased. 3. There is partial paralysis of the vaso-motor nerves to the superficial vessels, which dilate, causing flushing of the skin of the face and other parts. 4. The brain is partially anæsthetized; the rapidity of external impressions, the power of concentrated thought, and the discrimination of the senses, are all lessened, as is also sustained voluntary muscular power. 5. The temperature of the body is slightly depressed; but although there may be a decreased elimination of CO_2 by the lungs, there is no delay or diminution in the metamorphosis of tissue, for the excretion of urea in the urine is not affected. 6. The acidity and water of the urine are somewhat increased.

The long-continued immoderate use of alcohol leads to degenerative changes, primarily in the stomach and liver, and at a later period in the kidneys, lungs, brain, and bloodvessels. The degeneration is characterized by increased growth of interstitial fibrous tissue, which in course of time shrinks and causes atrophy of gland cells and loss of function. Chronic catarrh and cirrhosis of the stomach with cirrhosis of the liver, followed by

dropsy and hæmorrhage, are the well-known indications of the alcoholic tendencies of the individual.

The effect of intemperance in shortening life is now universally recognised. Statistics bear overwhelming evidence on this point. It may be stated generally that the mortality of the intemperate is from four to five times greater than that of the strictly temperate of the same age and in the same class of life. When the mortality of occupied males in 1890-1892, at ages ranging from twenty-five to sixty-five years, from alcoholism and diseases of the liver, is expressed as 100, and the mortality in each separate industry is reduced to a figure proportional to that standard, the following results are obtained by Dr. Tatham (Supplement to the 55th Report of the Registrar-General):

DEATHS FROM ALCOHOL AND DISEASES OF THE LIVER (1890-92).

Occupied males	100	Dock labourer	195
Coachman, cabman	153	Chimney-sweeper	200
Costermonger	163	Butcher	228
Coal-heaver	165	Brewer	250
Fishmonger	168	Inn-servant	420
Musician	168	Innkeeper	733
Hairdresser	175		

Dr. Tatham points out that the mortality from alcoholism is often registered as due to other causes that are known to be frequently associated with alcoholic excess, and this is often purposely done out of regard to the feelings of relatives. Experience proves that the liver is the organ which, more than any other, is affected prejudicially by intemperance.

Those engaged in the brewing and licensed victualling trades are notably an intemperate class; but, naturally, if the temperate men in these trades could be excluded, the figures indicating special disease of organs would be very much magnified.

All evidence points to the fact that alcohol, except in strict moderation, is injurious to men who are exposed to extremes of climate (great heat and great cold), or who have to undergo great bodily or mental labour. Its effect on the circulation is distinctly injurious to those engaged in hard bodily work, for it causes the heart to do more work without conferring any counterbalancing advantage.

In strictly moderate doses alcohol has not been proved to do any harm; and, taken in the form of beer or wine, many of the inhabitants of our large towns find it a useful aid to digestion and assimilation. A moderate dose may be taken to be 1 to 1½ fluid ounces of pure alcohol daily. But it must be remembered that there are idiosyncrasies as regards alcohol, and that what is harmless to one individual may be injurious to another. For thoroughly healthy people, alcohol in any form presents no advantages, and for children and young people it is decidedly injurious. The comparative immunity enjoyed by drunken persons from the usual effects of accidents is due to the paralysis of those nervous centres through which a shock would be produced in a condition of sobriety.

CONDIMENTS.

Vinegar is prepared by acetous fermentation from white wine or malt. It should contain from about 3 to 5 per cent. of glacial acetic acid. It is largely adulterated with sulphuric acid, which is injurious from its tendency to form insoluble sulphate of lime in the body. Acetic acid is neutralized in the system by soda, and ultimately becomes transformed into an alkaline carbonate.

Lemon and *lime juice* contain vegetable acids, chiefly

citric, about 30 grains in a fluid ounce. They are frequently mixed with water, and sometimes with other acids, such as sulphuric and tartaric acids. Lime-juice has generally a little less acid than lemon-juice. They are most valuable antiscorbutics.

These vegetable acids and their salts are also largely contained in all kinds of fresh fruit; but perhaps the chief advantage of fruit in a diet—when taken early in the day (before breakfast)—is its tendency to promote evacuation of the bowels.

Mustard is generally adulterated with wheat flour and turmeric, for the pure seed possesses too acrid a taste to be palatable; *pepper* with rice and minerals.

Pickles are now generally coloured with chlorophyll and vegetable colouring matters. Formerly copper was much used for this purpose.

Sweetmeats and *confectionery* are now almost invariably sold free from any injurious colouring matter. The coloration is imparted by careful heating of the sugar, by which a variety of shades of yellow and brown may be obtained, or by the use of such harmless vegetable matters as saffron, turmeric, annatto (yellow), cochineal (red), logwood (violet), and chlorophyll (green). The use of the mineral and metallic salts for colouring purposes—those containing iron, lead, copper, arsenic, chromium, and zinc—is now hardly practised at all.

An easy and rapid test for the separation of poisonous from harmless colouring matters may be applied as follows: Dissolve some of the sweetmeat in distilled water. If the colouring matter is soluble and is bleached on adding solution of sodium hypochlorite, it is organic and probably harmless. If the colouring matter is insoluble and is not bleached by sodium hypochlorite, it is mineral and probably poisonous.

The aniline dyes are but little used for colouring sweetmeats. They are soluble in alcohol and mostly innocuous, if quite free from arsenic, which is usually the case. Picric acid (trinitro-phenol or carbazotic acid), a yellow dye, is, however, injurious; and the same may be said of the yellow colouring matter derived from gamboge, and certain aniline dyes.

Tinned Foods.

Most articles of food when preserved in tins run some risk of contamination, owing to the metal being absorbed by the action of the juices confined in the tin.

To preserve the contents of the "tins," the lids are hermetically sealed down by solder when the contents are at the boiling temperature; and the partial vacuum thus created in the tins is evidenced by their tops and bottoms being slightly depressed from the outside. Should, however, there be any flaw in the "tins," or the solder seal be imperfectly applied, or should the heating process be ineffectually performed, then the contents may go bad. In this event, owing to the accumulation of the gases of putrefaction, the tops and bottoms of the "tins" become quite flat, and later on convex outwards, and the tin when struck gives out a hollow or drum-like sound. It is not difficult, therefore, in the majority of cases, to detect, before opening them, those "tins" in which the contents are bad.

CHAPTER IX.

THE CONTAGIA—COMMUNICABLE DISEASES AND THEIR PREVENTION—HOSPITALS.

The Contagia.

Certain diseases of men and animals have long been known to be communicable from one individual to another, and recent investigations have shown that some of these diseases are not only communicable from one individual of the same species to another, but are interchangeable between animals and men, and between men and animals. Various doctrines have been held at different times as to the nature of the contagia in these diseases, but the theory of their constitution which is embraced in what is known as the "germ theory of disease" need only be discussed here as being the most recent enunciation of the scientific study of disease causation, and as possessing certain inherent probabilities which are absent from the earlier beliefs on this subject. Whilst endeavouring to supply an explanation of such facts as are known about infection or contagion by the aid of the germ theory, it need not necessarily be assumed that any such doctrine is capable of satisfactorily explaining every occurrence in disease dissemination, or that a

finite settlement of a very profound and complex subject has been arrived at.

The germ theory, then, assumes that the contagia are microscopic living particles, organized in structure and for the most part capable of independent life both within and without the animal body. These organic particles are believed to form part of that large class the *schizomycetes*, which embraces the lowest and least developed forms of organic life, and constitutes a link, as it were, between the two great divisions of the animal and vegetable world. To this class belong the bacilli, micrococci, spirilla, vibrios, etc., which exist in such enormous numbers in the air, water, and soil in every region and climate, and to which, in conjunction with yeasts and moulds (fungi), the fermentative and putrefactive changes (to which all organized structures are more or less liable) are due.

The probability of the view that the particles of contagia are really minute organisms is favoured by the analogy of the processes of typical infectious disease in the human body to those of fermentation in an organic liquid. When the yeast plant obtains access to a saccharine fluid and the temperature is suitable, the cells of the yeast rapidly multiply, and after a certain time, which corresponds with the period of incubation in an infectious disease, changes are produced in the saccharine liquid, evidenced by the formation of alcohol and carbonic acid, which eventually render it incapable of being further acted upon by that particular ferment. So in infectious disease, there is a period of incubation which may be supposed to arise from the delay necessary to allow of the contagious particles overcoming the influences exerted against them by the antagonistic cells of the bodily fluids, thus enabling the growth and mul-

tiplication of the contagious particles to take place; during the course of the fever the pabulum suitable for the nutriment of the contagion is exhausted, or else the products of the activity of the contagious particles upon the cells of the body become in time directly poisonous to the contagia themselves, the fever terminates, and the body is rendered unassailable by a similar infection for months or years, or in some cases until the end of life.

It is evident that the contagion, once introduced into the animal body, grows and multiplies enormously. The least atom of infectious material serves to inoculate small-pox in a susceptible person, but the contagious matter produced in the course of the disease would be sufficient to inoculate many thousands. In each special disease the contagion multiplies chiefly in those tissues —the mucous and epithelial—which are more especially affected by it, and the infection is cast off from the body in large part with the secretions of these tissues. Freed from the body, the infection may be conveyed from the diseased to the healthy, or it may lie dormant in the clothes or furniture of the sick-room for long periods, but retaining its contagious properties.

This property, possessed by some of the contagia, of retaining unimpaired their powers of infection for long periods after leaving the body, points strongly in favour of their bacterial nature. It is known that many bacteria are propagated by sporulation, and that the spores, the immature forms of the adult species, can resist extremes of temperature and drying which are destructive to the fully developed organism. That liquids, gases, or any non-living material whatever could retain infective properties for long periods after expulsion from the body, when subjected to the disintegrating forces of the atmosphere, is at least highly improbable.

In some diseases, the contagion does not appear to be capable of retaining an independent existence outside the animal body. In these cases the infection is conveyed by direct contact.

It is not desirable to retain the term "contagious," as distinct from "infectious," in regard to the communicable diseases. For if, as is generally understood, the term "contagious" is limited to those diseases which are only transferable by direct inoculation, and "infectious" to those that have air- or water-borne contagia, an element of confusion is introduced; for most of the infectious diseases are inoculable, whilst the diseases which are generally spread by inoculation may at times be propagated through air or water. The term "zymotic" is usually limited to those communicable or infectious diseases which occur in epidemics; but here again, as "zymotic" commits us to the theory that the disease is dependent upon a living organized body of the nature of a ferment, it is not easy to understand why "zymotic" should not embrace the whole class of ailments in which a germ or microbial origin is considered probable.

A distinction may be made between "infection" and "intoxication"; by the former is implied an invasion of the body by a living germ, and by the latter the poisoning of the body by chemical agents, usually the products of the activity of the living germ. Anthrax affords a typical example of infection, in which the bacillus invades the whole body; and tetanus affords an example of "intoxication," for in this disease the bacillus is localized to the seat of injury, and the toxic products are absorbed from this spot.

The use of the word "specific" as applied to these diseases presupposes a specific origin for each—an origin, that is to say, from a pre-existing case of the disease

by means of a specific virus or organized living germ. The specific origin of a majority of the communicable diseases can hardly be doubted. The eruptive fevers are specific, they breed true; *i.e.*, a case of measles, for instance, cannot give rise to mumps or whooping-cough, but only to measles, and the infection cannot arise *de novo*, but must be sought for in a pre-existing case. The true specificity of some, however, such as diarrhœa, dysentery, and the hospital fevers (pyæmia, etc.), may be doubted, as it is at least probable that such diseases can at times arise from ordinary decomposition of organic matters, untainted with the virus of a pre-existing case.

The eruptive fevers are remarkable chiefly for occurring in epidemics, often at regularly recurring periods. The contagion being disseminated through the air, it is easy to understand how these diseases, once introduced into a community, spread with amazing rapidity, until the diminution of susceptible persons causes the epidemic to languish and finally die out.

There are other diseases which at times take on epidemic extension and virulence, but are mostly endemic; that is to say, they are habitually present in certain localities where conditions of excremental pollution of water, air, or soil favour the passage of the specific virus from one individual to another, with the constant occurrence of isolated or sporadic cases, which at certain seasons, when external conditions are favourable, give rise to the sudden and widespread dissemination termed an epidemic. The introduction of public water-supplies into towns has, no doubt, tended to cause certain epidemics of enteric fever and cholera to reach further and spread wider than formerly; for if a public water-supply is specifically polluted at its source, the contagion is carried to a far

larger number of households than could possibly be the case where each house has its own well or spring.

The tubercular virus, under certain favouring conditions, retains its infective properties after discharge from the animal body, and can then be transferred to healthy persons. The question of susceptibility, hereditary or acquired, to the tubercular virus is of the greatest interest, and is deserving of most careful investigation. It is evident that tubercle bacilli must be very widely scattered in the air of houses and towns, and yet the number of persons who contract tubercle is, relatively, infinitely small compared with the numbers that must from time to time be exposed to the contagion. Unlike the eruptive fevers, tubercular diseases run no definite course; and although it is now certain that recovery from tubercular lesions of the lungs, and perhaps of other organs, is by no means infrequent, yet there is no immunity conferred from subsequent attack.

The subject of bodily susceptibility to the action of the various contagia requires a passing notice. It is evident that in infancy and childhood the bodily susceptibility to various contagia is very great, and this susceptibility diminishes with advancing age. The protective influence of a previous attack in some diseases, the modifying influences of the state of health of the individual, of hereditary predisposition, and of individual or family idiosyncrasy, are well known to produce different conditions of bodily susceptibility; and there are other causes at work, less well known, but possibly equally potent. A plausible hypothesis as to the causes of these varying susceptibilities is the supposition that under these different conditions the vital actions of the body are not always equally potent to resist the invasion of the contagia. There is the battle of the cells of the

body and the bacteria, in which victory lies to the strongest, the weakness of the cell forces in certain cases constituting the special susceptibility to the action of the virus.

The microbial origin of some of the communicable diseases may be considered to be established beyond doubt, and this fact is a strong argument in favour of the remainder—in which no such connection has as yet been positively traced—being causally dependent upon specific micro-organisms. Koch has laid down certain conditions, upon the proof of which alone can it be definitely stated that a particular micro-organism is the cause of a certain disease. They are as follows:

1. The micro-organism must be found in the blood, lymph, or diseased tissues of man or animal, suffering from or dead of the disease.

2. The micro-organisms must be isolated from the blood, lymph, or tissues, and cultivated in suitable media outside the animal body. These pure cultivations must be carried on through successive generations of the organism.

3. A pure cultivation thus obtained must, when introduced into the body of a healthy animal, produce the disease in question.

4. In the inoculated animal the same micro-organism must again be found (E. Crookshank, "Bacteriology").

It is evident that, postulate No. 3 being inapplicable to human beings, the complete sequence of proof cannot be arrived at in the case of solely human diseases. But in the case of the diseases affecting both men and the lower animals, inasmuch as the animals can be submitted to processes of inoculation, the entire chain of proof can be substantiated. The list of diseases of the lower animals which are dependent upon specific microbes

for their origin and propagation is now very extensive, including fowl cholera, malignant œdema, pyæmia, septicæmia, and various suppurative diseases in rabbits, guinea-pigs, mice, etc., swine fever, cattle plague, foot-and-mouth disease, and many others.

The diseases of animals common to man, in which a specific bacterium has been isolated, are anthrax (malignant pustule in man), tubercle, glanders, actinomycosis, erysipelas, tetanus, plague, and foot-and-mouth disease.

Anthrax, Malignant Pustule, or Wool-sorter's Disease.—The bacilli are found in enormous numbers in the blood of animals dead of anthrax. They form spores when exposed to the air, which are much more resistant to extremes of heat and drying and to chemical reagents than the fully-developed bacilli.

Tubercle.—The *Bacillus tuberculosis* is found in all tubercular deposits, and is seen with a high power of the microscope to consist of small, usually curved rods. The bacilli are found in the sputa of phthisical patients; and in man the disease is set in action by the bacilli introduced, according to the usual method, through the mucous membrane of the air passages or intestinal canal, or occasionally by direct inoculation into a wound or abrasion of the skin.

In the lower animals (monkeys, cattle, fowls, guinea-pigs, rabbits, etc.) artificial tuberculosis can be readily produced by inhalation of a spray containing tubercle bacilli, by feeding experiments with tuberculized food, and by direct inoculation, the channels of infection being the same as those of man.

Glanders.—The bacillus of glanders (*Bacillus mallei*) consists of rods about the size of tubercle bacilli. The inoculation of pure cultivations into horses produces the

characteristic disease, the bacilli being found after death in the affected organs and diseased tissues.

In *erysipelas*, a streptococcus has been found occupying the lymphatics of the skin at the circumference of the erysipelatous blush. A pure cultivation of the streptococci produces erysipelatous inflammation when inoculated into animals and into men (as has been done for the relief of lupoid and cancerous affections).

The specific organism in *tetanus* is a bacillus which probably exists widely distributed in dust, dirt, and in soil. The bacillus gains an entrance into the body through scratches and wounds inflicted by substances contaminated with dirt containing the organism. Cases of so-called idiopathic tetanus are probably due to similar inoculations through scratches or wounds that have passed unnoticed. Brieger has separated a ptomaïne, called *tetanin*, from an impure culture of the bacillus, which, when injected in minute quantity into animals, produces tetanus.

Klebs, Loeffler, Roux, and Yersin have isolated a bacillus from the surface of the mucous membrane in cases of *diphtheria*. From cultivations of this bacillus a soluble poison has been obtained, which causes the symptoms of diphtheria in varying degrees of intensity according to the dose. This poison is not an alkaloid—a ptomaïne—but appears to be allied to the ferments, as it is precipitated by alcohol, and therefore cannot be of alkaloidal nature. It may possibly be an albumose.

The bacillus of *typhoid* fever (now known as the Eberth-Gaffky bacillus) is almost constantly present in the alimentary canal, in the mesenteric glands, and in the spleen of fatal cases of this disease. An attempt has been made to prove the identity of this bacillus with the *Bacillus coli communis*, which is a constant and normal

inhabitant of the large intestine and lower portion of the small intestines of man and mammalian animals under perfectly healthy conditions. Dr. Klein, however, has shown that the two bacilli are morphologically and culturally distinct. Placed in water, the two bacilli co-exist well together ; but the *Bacillus coli* is capable of preserving its vitality in water for a longer period than the typhoid bacillus. In sewage likewise, the *Bacillus coli* flourishes, whilst the typhoid bacillus gradually diminishes in numbers and ultimately disappears. The cultural characteristics of the two bacilli do not in the least alter during their sojourn in water or sewage ; and there is no evidence at present in support of the view that the *Bacillus coli* can become transformed into the typhoid bacillus whilst sojourning in sewage or elsewhere, or can in any way become imbued with the pathogenic properties of the latter organism.

It is a curious circumstance that the typhoid bacillus when planted in sewage to which potassium nitrate has been added (1 per cent.) retains its vitality for a considerable period, and undergoes rapid and continuous multiplication. Crude sewage is, as a rule, free from nitrates, whilst sewage which has been filtered through soil contains nitrates as the result of oxidation ; this may be the reason why well waters polluted by drain or cesspool leakage through the soil have the capacity, apparently, of retaining for considerable periods the infective properties introduced by the specific pollution.

There are some other diseases whose microbial origin is not yet definitely established, but in which there is a very strong probability of such a mode of occurrence. Chief among these is *leprosy*. In this disease, fine rod-like bacilli, many of which have spores, are found in enormous numbers in the leprotic tubercular lesions.

They probably spread through the body by means of the lymphatics, as they are not found in the blood.

From vaccine lymph a streptococcus has been isolated, which is believed to be the specific organism of *vaccinia;* from acute abscesses, boils, carbuncles, the abscesses of pyæmia, acute osteo-myelitis, and puerperal fever, the *Staphylococcus pyogenes aureus* and *albus* have been obtained, which are pathogenic to certain animals. A bacterium (pneumococcus, Fraenkel and Weichselbaum) has been found in the exudations of croupous pneumonia, which is pathogenic to mice, inducing a very acute septicæmia. This pneumococcus or diplococcus is also said to be present in the saliva of healthy people who have suffered from pneumonia. Its presence may explain the liability to recurrence of this disease, in association with chill or other exciting cause. In ulcerative endocarditis a micrococcus has been observed in the endocardial ulcerations. In Asiatic cholera, Koch discovered a comma-shaped bacillus in the intestinal walls and evacuations. In relapsing fever, a motile spirillum (*Spirillum Obermeieri*) has been found in large numbers in the blood during the relapses, which organism is absent in the non-febrile periods, and which, when inoculated into monkeys, induces a disease analogous to human relapsing fever. Laveran attributes malarial attacks to a protozoon, or vegetable micro-organism, called *plasmodium*, which has been found in the blood of man during malarious illness, and also in the blood of some of the lower animals. A streptococcus is believed to be the specific microbe of scarlet fever (Klein); and various micro-organisms have been described as associated with other diseases.

There is still wanting, in the case of some communicable diseases, the complete chain of experimental proof necessary to establish the causal relationship of the

organisms which have been described as associated with them. The experimental inoculation of the lower animals with the supposed viri of human diseases to which they are not known to be naturally liable affords little assistance to the completion of the proof, even if symptoms are produced in the animal of an analogous nature to those characteristic of the disease in man. The constant association of a certain organism with a certain disease, in all climates and races of men, is, no doubt, practically a strong point in favour of the specific nature of the microbe, but logically it does not prove that the microbe is an indispensable antecedent (cause), or even an antecedent (one of several causes in conjunction) of the disease, or, indeed, that it is anything more than a consequence.

Recent research seems to point to the symptoms of infectious disease being caused not directly by the action of the microbes themselves upon the tissues, but by the production of soluble poisons of the nature of alkaloids, and termed "toxins." Observations have already been made in the cases of anthrax, tetanus, diphtheria, puerperal fever, and rabies, that these diseases are—or may be—caused by the specific microbes producing, as the result of their activity, soluble poisonous alkaloids or toxins, which exert a direct action upon the tissues of the body; and if such is the case in these diseases, the symptoms of many others of an allied nature may also be due to the chemical products of the microbes, and not to the direct action of the microbes themselves upon the tissues. There is a matter of practical interest involved in this point; for although the microbes themselves may be destroyed by boiling or other application of heat, their chemical products may be able to resist these high temperatures, and retain their poisonous

powers unimpaired. Still, as far as our knowledge at present extends, the microbes, although only the makers of the poisons which directly affect the body, are the principal or only means of spreading infection.

On the introduction, then, of the microbes of specific disease within the body of an animal, we may assume that poisonous products are sooner or later produced. Whether the disease will develop, and what form of mildness or severity it will assume, depends, according to Metschnikoff's theory, upon the powers of the white corpuscles or leucocytes (macrophages) of the bodily fluids to grapple with the producers of these toxic products. Should the animal have already undergone preventive inoculations with attenuated virus, it appears that the leucocytes, having already become accustomed to the microbic poisons, are able to struggle with and destroy the parasites on their entrance, and the disease is not developed. This theory of Metschnikoff is not, however, universally credited; and it is by some supposed that the "defensive" action, or immunity, is due to the presence of proteid ferments (globulin) in the bodily fluids, that have a distinct germicidal action on pathogenic bacilli (Hankin). This defensive power of blood serum is believed to be due to a globulin which is one of its constituents.

Again, there is the theory, supported by Pasteur and Klebs, as to the causation of the immunity which is acquired from a previous attack. They believe that the bacteria use up their special food pabulum, and as a fresh supply is not afterwards produced, a second attack becomes impossible. Against this theory there is the fact that the products of living germs are now known to produce immunity, and these could not use up the food material. By another theory the bacteria are assumed

to leave behind them in the tissues some product (antitoxin) whieh inhibits the growth of the same species; and a fourth theory argues that the cells are so modified during attack as to be able to resist future invasion of the same species: this last is known as the "acclimatization" theory.

The decline of an infectious disease is possibly connected with the accumulation in the body of the toxic products of the microbes, which tend in time to destroy their life and activity; for we know that putrefactive bacteria produce, by their action upon albuminous substances, certain antiseptics, amongst which are cresol, indol, skatol, and compounds of phenol, which destroy these organisms; and the reasoning may be extended by analogy to the pathogenic microbes.

Preventive inoculations may be made with attenuated virus, *i.e.*, with cultures of the microbes weakened by exposure of successive generations to heat (not sufficient to destroy them altogether), or by growing the microbes in culture media medicated with some antiseptic, or by passage of the microbes through animals of different species; or the inoculations may be made with the soluble chemical poisons produced by the virus during its growth in nutrient media. Preventive inoculations by the latter means alone have already been carried out in the case of anthrax, chicken cholera, diphtheria, and mouse septicæmia; and the attenuated virus of rabies (Pasteur's method) is probably only the chemical products of the microbe's growth, and not any form of the microbe itself. This method of chemical vaccination has only recently been studied; but competent authorities believe that in it lies the future of protective inoculation, and that further research will enable definite chemical compounds to be produced, which under some conditions

may be made to give rise to the symptoms of disease in their acutest forms, and under others produce acquired immunity, without any disease manifestation.

Within the last few years it has been shown by Behring, Kitasato, Hankin, Tizzoni, and Cattani, that animals may be rendered immune to diphtheria, tetanus, and septic affections, by repeated subcutaneous injections of the toxins produced when the specific microbes of these diseases (*Klebs-Loeffler bacillus*, *Tetanus bacillus*, *Streptococcus pyogenes*) are grown in suitable culture media. The toxins in the culture liquids are made to pass through a porcelain filter, before injection, in order that all microbes may be arrested. When the process of immunization is complete—several months being usually required to attain completion by means of graduated injections, so that the health of the animal (usually a horse) may not seriously suffer—the serum of the blood is found to possess antitoxic, *i.e.*, defensive properties against the toxins of the particular disease. The blood of the animal is accordingly drawn off from a large vein, and the serum separated with all proper antiseptic precautions, and finally stored for use. Not only has the serum the power of conferring immunity, when injected into the human body, against subsequent attack, but it also has the power of arresting the disease already commenced, if employed within a short period of onset. As is now well known, diphtheria antitoxic serum has been widely used, and has met with great success, in the treatment of diphtheria; and the treatment of tetanus by antitoxic serum has been successfully inaugurated. The treatment of septicæmia and puerperal fever by antistreptococcus serum, and of acute pneumonia by antipneumococcic serum would also probably come into frequent use, were not these diseases

very often the result of infection by more than one species of micro-organism. The list of diseases to be counteracted by the use of antitoxic serums will certainly be largely extended in the near future. Already claims have been established for the treatment of typhoid fever and Oriental plague by this means; and in India large numbers of people have undergone protective inoculations with cultures of comma bacilli against the poison of Asiatic cholera (Haffkine's method). Sera for the treatment of syphilis, tuberculosis, leprosy, yellow fever, and snake venom, have been prepared, but have not in all instances attained their object. Tuberculin, however, is of great value for diagnostic purposes.

The serum diagnosis of acute specific fevers is now attracting attention, more especially in relation to Malta fever and enteric fever. Durham and Gruber have shown that whenever the micro-organisms, which are causally associated with these diseases, are brought into contact with the serum or plasma of an animal or a patient who is undergoing, or has undergone, an attack of the disease in question, the following succession of phenomena, or some of them, manifest themselves: (1) The bacteria become agglutinated, or clump; (2) the bacteria lose their motility; (3) the clumps of agglutinated bacteria sink to the bottom of the tube, and the culture fluid, which was previously evenly turbid, becomes clarified; (4) the bacteria shrink up into the form of minute spherules; (5) the bacteria are definitely devitalized.

The possibility of insects carrying pathogenic organisms has been demonstrated in the case of anthrax, plague, and cholera, and less certainly in the case of typhoid fever and Egyptian ophthalmia. Blood-sucking insects may transmit disease directly from the sick to the healthy,

and such a mode of transmission is possible in anthrax, septicæmia, pyæmia, erysipelas, and plague. The matter is still *sub judice*, but there are good grounds for the belief that recurrent fever, leprosy, tuberculosis, and yellow fever may also be thus communicated.

Insects, moreover, may transport the eggs of animal parasites (*Tænia solium*, *Trichocephalus dispar*, *Ascaris lumbricoides*, etc.), and deposit them on food.

Communicable Diseases.

Small-pox and Vaccination.

The incubation period of small-pox is nearly always twelve days, but may vary from nine to fifteen. When the virus has been inoculated, the incubation is said to be shorter—only seven or eight days. The incubation period of *variola nigra* is said to be only six or seven days. Small-pox is communicable from the earliest appearance of the symptoms, and the ordinary duration of infectiveness is from three to four weeks. There can be little doubt that the contagion is most active, and the infectivity greatest, during the period of maturation and crusting of the pustules. The virus is contained in the mouth and throat secretions of the patient and in the skin eruptions, and may be conveyed for considerable distances through the air in the dried epithelial scales and pus cells from the crusted pocks.

The exceptional incidence of small-pox in the immediate neighbourhood of some of the London small-pox hospitals, in which were formerly treated during epidemic periods large numbers of cases, can admit of but one explanation, viz., that when a sufficient number of cases in the acute stages are collected together in one building on a small area of ground, the hospital becomes a centre

of infection to the surrounding neighbourhood. In the diagram (Fig. 82) taken from Mr. Power's Report to the Local Government Board, 1885, the neighbourhood around the Fulham Small-pox Hospital is divided into special areas by circles of $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, and 1 mile radii. In these special areas the figures show the percentage of houses in each area invaded by small-pox in the period May 25, 1884, to September 26, 1885. The extreme incidence of the disease in the $\frac{1}{4}$-mile circle surrounding the hospital is at once apparent, and is attributed by Mr. Power to the aerial diffusion of the infection. The exceptional incidence in the quadrant lying south-east of the hospital is noteworthy, and may possibly be attributed to the greater prevalence of north-westerly winds during the period included. But it should be stated that this central $\frac{1}{4}$-mile circle, containing, as it did, only a few hundred houses, was somewhat exceptionally liable to be capriciously affected.

Dr. Barry's report on the small-pox epidemic at Sheffield shows that the small-pox hospital, situated in a thickly populated locality in the centre of the town, was also instrumental in disseminating the disease through the "special area" surrounding the hospital, as soon as a number of acute cases were concentrated in it. But when the patients were removed to a new hospital erected outside the borough, the excessive incidence of the disease upon the area surrounding the old hospital disappeared. Whether small-pox in these cases was transmitted aerially or by personal communication cannot be decided, as the faulty administration of the hospital may have allowed the transmission of small-pox by the persons of the hospital officers, or of visitors to the hospital.

Dr. Arnold Evans has shown the influence of the

Bradford Fever Hospital in 1893 in disseminating small-pox in the special area around it. The per cent. incidence rate on houses within the $\frac{1}{4}$-mile radius was 10·4; on houses within the $\frac{1}{4}$ to $\frac{1}{2}$ mile area 6·8; on houses within

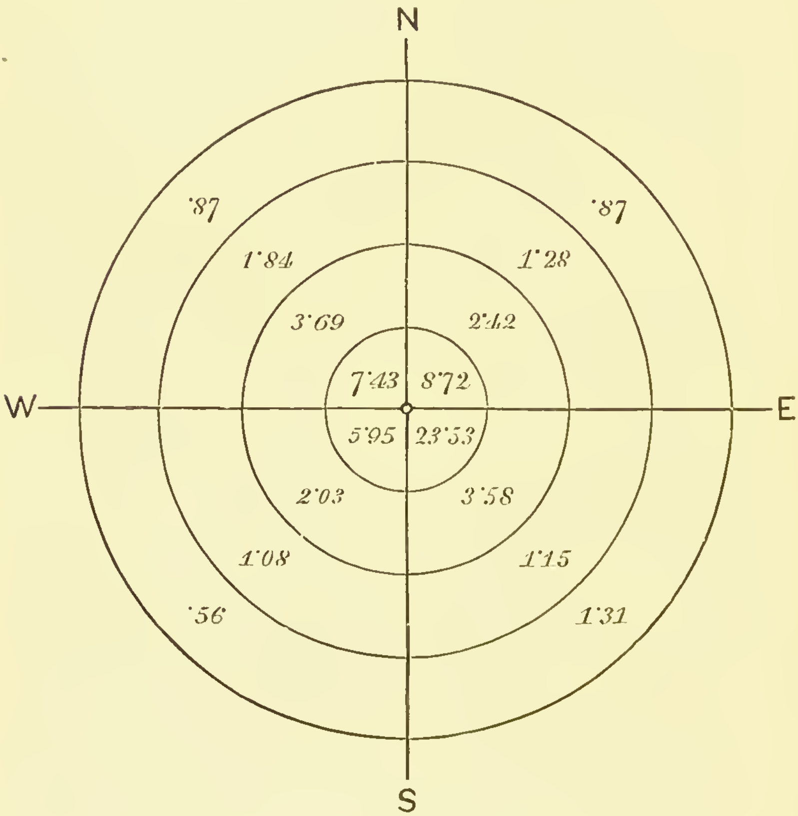

FIG. 82.—FULHAM SMALL-POX HOSPITAL.

Special area divided into sections of $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, and 1 mile radii, showing in different areas the number of houses (out of every 100) invaded by small-pox, in the period May 25, 1884, to September 26, 1885.

the $\frac{1}{2}$ to $\frac{3}{4}$ mile area 2·1; and on houses within the $\frac{3}{4}$ to 1 mile area 1·0. The incidence rate on the whole borough during the period was 0·6 per cent. The quadrant lying north-east of the hospital in the special 1-mile area

suffered most—7·06 per cent. of houses invaded; then followed the south-east quadrant, 5·28 per cent.; the south-west quadrant, 2·93 per cent.; and the north-west quadrant, 2·4 per cent. It is noted that on 250 days of that year the prevailing winds were westerly, and only on eighty-three days was the wind persistently from the east.

After reviewing all the circumstances, Dr. Evans formed the opinion that the most likely manner to account for the extensive prevalence of small-pox over the special area was that the poison was conveyed aerially direct from the wards of the hospital.

As regards the number of cases aggregated in a hospital necessary to enable it to exert an influence on the surrounding neighbourhood, Dr. Power's reports of 1884-5 show that this influence was exerted when the number of *acute* cases had been restricted to twenty; whilst on one occasion he found the excess of small-pox in the neighbourhood of the Fulham Hospital was quite remarkable at a time when the total admissions to hospital had not exceeded nine, only *five* of these being cases in an acute stage.

On the other hand, Dr. Savill (Warrington outbreak, 1892-3) and others have found that there were so many elements at work for the conveyance of infection by direct means along the lines of human intercourse (more especially in the vicinities of the hospitals), that the hypothesis of aerial convection is held to be unnecessary. That a small-pox hospital in a poor and crowded locality may be, and usually is, a source of infection to the surrounding neighbourhood is not denied; but the incomings and outgoings of the staff, the calls of tradesmen and friends of the patients, and the bringing of the patients to the hospitals, are all dangers which of necessity become

intensified as the centre is approached, and may in themselves account for this circumstance.

One consideration which causes many to doubt the correctness of the aerial convection theory is the immunity from attack constantly observed in the large numbers of presumably susceptible individuals living near small-pox hospitals. Moreover, no infection has, so far as known, spread to the passengers in boats and ships passing up and down the Thames at Long Reach, where the London small-pox ships are now moored, the explanation being that in this case the element of direct or indirect personal communication is non-existent. Dr. Power's views, then, are thought by many to be adequately explained by the possibilities of direct or mediate infection from the hospital.

A Local Government Board circular on "The Provision of Isolation Hospital Accommodation by Local Authorities" has, with a view to lessening the risk of infection from small-pox hospitals, laid down the rule that a local authority should not contemplate the erection of a small-pox hospital—first, on any site where it would have within a quarter of a mile of it as a centre either a hospital, whether for infectious diseases or not, or a workhouse, or any similar establishment, or a population of 150 to 200 persons; and secondly, on any site where it would have within half a mile of it as a centre a population of 500 to 600 persons, whether in one or more institutions, or in dwelling-houses. Cases in which there is any considerable collection of inhabitants just beyond the half-mile zone should, says the circular, "always call for especial consideration."

The contagion clings persistently to infected clothing, bedding, and furniture, and is often communicated by means of these infected articles.

Before the introduction of vaccination small-pox epidemics occurred once every three years, and possibly oftener, and were attended with a fatality and injurious consequences, such as loss of eyesight, which it is difficult at the present time to realize.

Like many other specific infectious diseases, small-pox has a special seasonal prevalence (see Fig. 83). From observations covering a long period of years, it has been possible to describe a curve showing the weekly mortality of this disease as a percentage above or below the mean mortality for the year. From the diagram it will be seen that the average London mortality is greatest during the first six months of the year, rising to a maximum towards the end of May and falling through June, until it descends below the mean line, where it fluctuates during the last six months, to again rise in December or January.

Small-pox is a disease of every climate and every race, and attacks all ages and both sexes unprotected by a previous attack or by vaccination. In this country, however, it causes a somewhat higher death-rate amongst males than amongst females, showing either a greater susceptibility to attack on the part of males, or a greater chance of an attack proving fatal in their case. Thus, the average death-rate for males at all ages in England during the years 1854-87 was 0·183 per 1,000 living; whilst the death-rate for females at all ages was only 0·148 per 1,000 living. It arises solely from the contagion of a previous case, and although its severity may be intensified by uncleanly and over-crowded houses and insanitary surroundings, as is the case with all infectious diseases, it cannot be originated by any such conditions. It is probable that during epidemic periods small-pox is very frequently spread by the number of

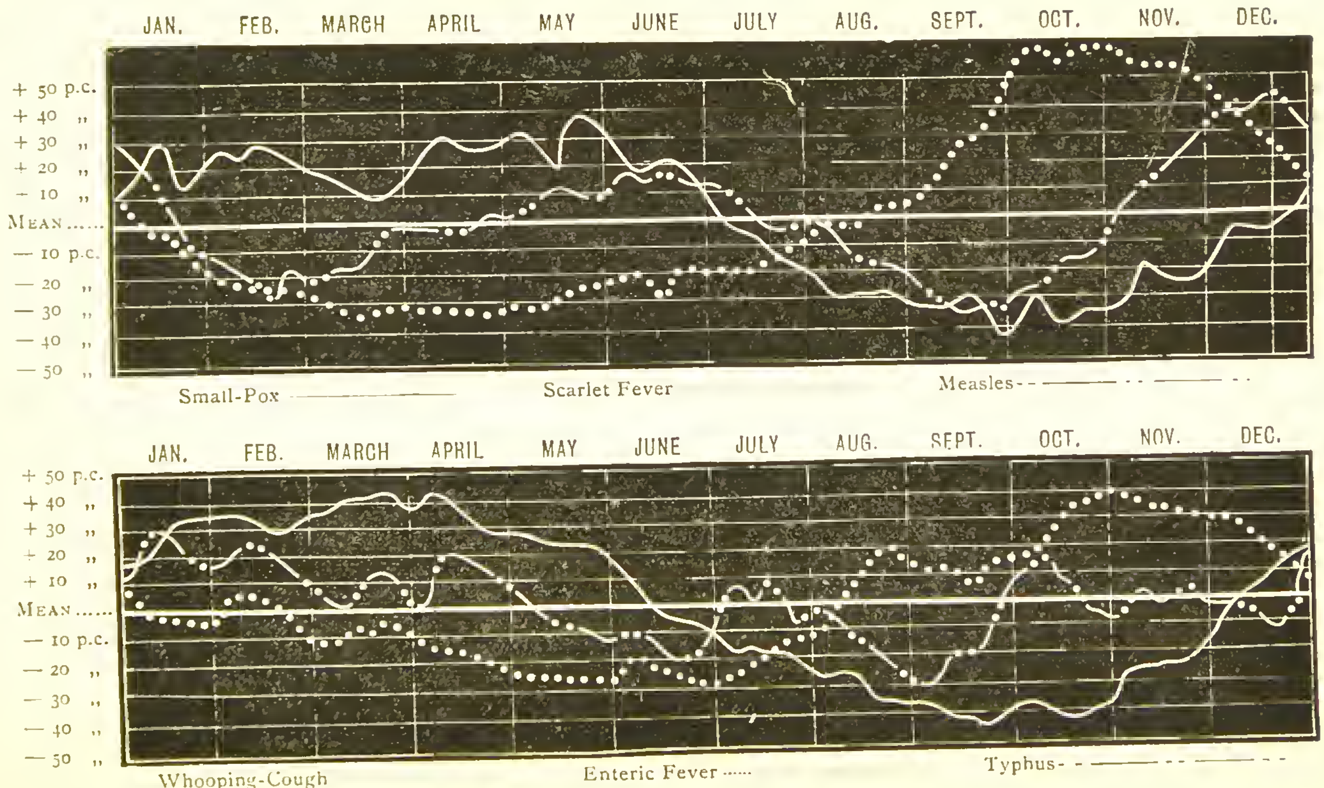

FIG. 83.—The curves represent the average death-rates in corresponding weeks of a period of years, calculated in percentages of the mean weekly death-rate of the whole period (after Buchan and Mitchell).

mild and not easily recognisable cases of the modified disease in vaccinated persons that invariably occur, and the failure to distinguish chicken-pox from this type. The virus from such mild forms is capable of imparting a very virulent form to unvaccinated persons, and the same holds true of nearly all infectious diseases. The mildest types often propagate contagion of the most virulent description.

Many outbreaks of small-pox have been traced to tramps—a class of people who are practically exempt from any sort of sanitary supervision. To obviate this danger, the local authority should be empowered to require a medical examination of all persons entering common lodging-houses and casual wards, and to enforce the temporary detention of the inmates of any common lodging-house in which a case of small-pox has occurred.

Previous to the discovery by Jenner, towards the end of the last century, of the protection afforded by the inoculation of cow-pox lymph against the attacks of small-pox, small-pox was a disease from which few escaped. From 1750 to 1800, small-pox caused nearly one-tenth of the total number of deaths (96 out of every 1,000 deaths from all causes), and in epidemic years—1796, for example—this fatality was occasionally nearly doubled. So universal was the disease, and so frightful its disfiguring effects and the risk of loss of sight, that the practice of inoculation, introduced originally from Constantinople by Lady Mary Montagu, became very general during the latter half of the eighteenth century. The fatality of the disease so imparted was found to be much less than that of natural small-pox, 2 or 3 per cent. of the cases ending fatally instead of 20 or 30 per cent.; but the infection was thereby enormously multiplied all

over the country, and the epidemics became more frequent than ever.

Jenner published the result of his researches in 1798, and since that time vaccination has made steady progress throughout all classes of the population, with the result of gradually diminishing the frequency of epidemics, the severity of the disease, its incidence on the population, and its death-rate. In 1838 gratuitous vaccination was provided, and in 1854 vaccination became compulsory for all infants above the age of three months; but it was not until 1871 that Boards of Guardians were obliged to appoint public vaccinators for their districts. From 1838 to 1853 the death-rate from small-pox in England and Wales averaged 0·42 per 1,000 persons living; from 1854 to the present time the average is not more than 0·2 per 1,000. At the same time the proportion of small-pox deaths to deaths from all causes has fallen

MEAN ANNUAL DEATH-RATES FROM SMALL-POX AT SUCCESSIVE LIFE PERIODS, PER MILLION LIVING, AT EACH SUCH LIFE PERIOD.

	All ages	0-5	5-10	10-15	15-25	25-45	45 and upwards
I. Vaccination optional (1847-53)	305	1617	337	94	109	66	22
II. Vaccination obligatory, but not efficiently enforced (1854-71)	223	817	243	88	163	131	52
III. Vaccination better enforced by vaccination officers (1872-91) ..	89	177	95	54	97	86	38

gradually from nearly 100 per 1,000 (or $\frac{1}{10}$) in the last century, to an average of about 10 per 1,000 (or $\frac{1}{100}$) from the year of compulsory vaccination to the present time. The average death-rate from small-pox in the

last century was probably not less than 3 or 4 per 1,000. During the ten years 1881-90 the average death-rate in England was only 0·05 per 1,000, notwithstanding the increased facilities for the spread of the disease resulting from the greater crowding on area of the population during recent years.

This great decline in the mortality from small-pox is, however, entirely confined, as regards the last forty years, to the early periods of life (under the age of fifteen). Under the age of five years the death-rate from small-pox has even been reduced 80 per cent. in the last thirty years.* But the death-rate has increased at all ages subsequent to fifteen years. The explanation is obvious. Compulsory vaccination in infancy has saved the lives of an enormous number of children, who formerly died of small-pox, and has served to reduce the death-rate from small-pox at all ages. After the age of fifteen the protective influence of the primary vaccination has to a large extent disappeared; and unprotected adults form a larger proportion of the population than in the earlier periods, when an attack of small-pox in childhood was far more common, and, as a rule, gave immunity from the disease for the rest of life.

It was at first thought that one vaccination afforded protection to the individual against small-pox for the rest of life. This is now known not to be the case—with regard to infantile vaccination, at least. In the first place, the efficacy of vaccination depends largely upon the efficiency of the operation and the number and character of the resulting scars. Secondly, the protective influence wears away with the lapse of time, and re-

* The large mortality from small-pox amongst infants under one year of age is largely due to deaths of infants from this disease when less than three months old, *i.e.*, before vaccination has been performed.

vaccination at or before the age of puberty is a measure the utility of which cannot be doubted. Calf lymph, and that from a vaccine vesicle of the eighth day from a healthy infant, if used perfectly fresh, are probably capable of giving equally good results.

The protective effects of vaccination have been studied chiefly in relation to the fatality and severity of the disease in the vaccinated and unvaccinated. But this, it must be remembered, is only one side of the question, and the relative incidence of the disease on these two classes is deserving of study. The exact proportion of unvaccinated to vaccinated in the community is not definitely known, but taking it at its highest figure, the unvaccinated probably do not form more than 10 per cent. of the total population. On the other hand, the unvaccinated certainly form not less than 30 per cent. of the cases treated in small-pox hospitals, and the proportion of severe and hæmorrhagic cases is far larger amongst the unvaccinated than the vaccinated.

The fatality of the disease in the two classes is illustrated in the diagram, founded on figures supplied by Dr. Collie, for the two epidemic years of 1871 and 1881, of cases treated in London small-pox hospitals (Fig. 84). Under fifteen years of age and over fifteen years the mortality per cent. of cases in the unvaccinated is nearly identical, viz., 37 or 38 per cent.; whilst under fifteen the influence of the number and character of the scars in the vaccinated is seen to be of not nearly so much importance as over fifteen. The evanescence of the protective influence of primary vaccination after the age of fifteen is thus well exhibited: for whereas one or more bad marks reduce the mortality to 4 per cent. under fifteen, over fifteen the mortality of cases with one or more bad marks is 10 per cent. Taking nearly 7,000 cases observed in

recent years, the Royal Commission on Small-pox and Vaccination found that the small-pox fatality rate in persons with one mark was 6·2 per cent.; with two marks, 5·8 per cent.; with three marks, 3·7 per cent.; and with four marks, 2·2 per cent.

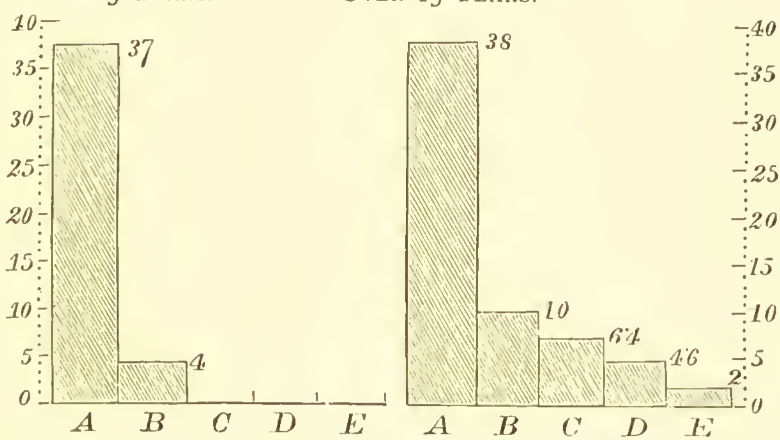

FIG. 84.—SMALL-POX EPIDEMICS, 1871, 1881: MORTALITY PER CENT. IN FEVER HOSPITALS (LONDON).

−15	+15	
(386)	(174)	A = unvaccinated.
(222)	(483)	B = one or more bad marks.
(76)	(141)	C = one good mark.
(44)	(151)	D = two good marks.
(70)	(100)	E = three good marks.

Revaccination at puberty, if properly performed, confers almost absolute immunity from small-pox for the remainder of life; and if by any chance a revaccinated person should acquire small-pox, the disease assumes its mildest type. In Prussia since the year 1874, when vaccination and revaccination became compulsory, the death-rate from small-pox has been reduced to one-tenth of its former rate, viz., from 0·24 per 1,000

to 0·02 per 1,000; and it is stated that in the Prussian Army there has not been a single death from small-pox from 1874 to the present time.

In Germany, with a population of over 50,000,000, surrounded on three sides by badly-vaccinated countries, small-pox has been almost stamped out, and during the ten years 1885-95, 79 per cent. of the few cases which occurred were resident on the frontiers; whereas in Austria and Belgium, where vaccination is not compulsory, the death-rates from small-pox are more than twenty-fold as great. The great immunity which Germany enjoys is due to the fact that in that country vaccination and revaccination are compulsory. The compulsory vaccination age is the second year of life, and it is significant to note that in 1886-90 more than two-fifths of the few deaths that occurred from small-pox were under two years of age. Revaccination is performed in Germany at the end of the period of compulsory school attendance, and every recruit is revaccinated on joining the army.

Dr. Barry found in the Sheffield epidemic of 1887-88 that unvaccinated children under ten years are twenty times more liable to attack than the vaccinated, and unvaccinated persons over ten are five times more liable; and in unvaccinated children under ten the attack is twenty-two times more likely to be fatal than among the vaccinated, while in unvaccinated persons over ten the risk of an attack proving fatal is eleven times as great. Therefore, during small-pox prevalence, an unvaccinated child under ten is 440 times more liable to die than a vaccinated one, and an unvaccinated person over ten is fifty-five times more likely to die than a vaccinated one. Moreover, 17·2 per cent. of the attacks were severe among those vaccinated, while among the unvaccinated 81 per cent. were severe; and in children under ten years 9 per cent.

of the attacks were severe among those vaccinated, and 78 per cent. among those unvaccinated.

In houses invaded by small-pox, in the course of an outbreak, not nearly so many of the vaccinated inmates are attacked as of the unvaccinated, in proportion to their numbers. Taking children under ten in invaded houses, in Dewsbury, 10·2 per cent. of the vaccinated were attacked, and 50·8 per cent. of the unvaccinated; in Leicester, 2·5 per cent. of the vaccinated, and 35 per cent. of the unvaccinated; and in Gloucester, 8·8 per cent. of the vaccinated, and 46·3 per cent. of the unvaccinated.

It is the custom for antivaccinators to attribute the reduction in small-pox incidence to improved sanitation; but improved sanitation will not account for—(1) the fact that small-pox mortality has been transferred from childhood to the later periods of life since vaccination has been introduced. Whereas in Germany, where vaccination is not compulsory till the second year of age, over 40 per cent. of all the small-pox mortality occurs under two years of age. (2) The immunity enjoyed by revaccinated postmen and nurses. The revaccinated nurses at the Leicester Small-pox Hospital escaped, while those who refused revaccination were attacked. (3) That the disease passes by the vaccinated children, but attacks the unvaccinated living *in the same house*, as in Dewsbury, Leicester, and Gloucester. (4) The lessened fatality among the vaccinated if attacked. (5) That those with three or four vaccination marks are less liable to a fatal attack than those with one or two. (6) The great immunity which Germany enjoys even as compared with Great Britain. Finally, the disease has never been shown to be caused, directly or indirectly, by any insanitary condition.

The isolation of small-pox cases in hospitals is a useful auxiliary to vaccination, but it is not a sufficient substitute

for it, owing to the inevitable failure to secure isolation, in all cases, with the necessary thoroughness and promptness. Such failure results from parents not observing the early symptoms of the illness, the neglect to call in a doctor, the difficulties of diagnosis, the delays in removal, the probable inadequacy of the hospital accommodation during an epidemic, and the possible inefficiency of the disinfection of infected articles.

The operation of vaccination, if properly performed with clear fresh lymph, does not impart any other disease but vaccinia. Among the maladies which have been attributed to vaccination are: syphilis, erysipelas, diarrhœa, tabes mesenterica and scrofula, bronchitis, cancer, leprosy, and many forms of skin disease.

Vaccino-syphilis has, however, in the past happened so rarely as to have been a clinical curiosity. With the general introduction of calf lymph it will disappear altogether, as calves are not subject to syphilis. Vaccino-syphilis has often been confounded with a congenital syphilis, latent until lighted up by vaccination. The acquired syphilitic rash, however, appears at the earliest from fifty to ninety days after vaccination, and in every case a chancre forms at the site of vaccination. The syphilitic chancre is limited to one or two points of inoculation, inflammation is slight, loss of substance is superficial, and the parchment induration is typical (Fournier). That the increase in infantile syphilis is not due to vaccination, as asserted by the antivaccinators, is shown by the fact that whereas in England and Wales, with vaccination generally enforced, the increase in the infant mortality from syphilis between the two periods, 1863-67 and 1883-87, was 24·7 per cent., in Leicester, where vaccination has been neglected, the increase was no less than 69·3 per cent.

As to vaccino-erysipelas, this disease has doubtless frequently resulted from vaccination, either directly from the failure to take due precautions as regards cleanliness at the time of the operation, or, indirectly, from exposure to dirt and insanitary conditions in the home of the recently vaccinated infant. The frequency of occurrence of vaccino-erysipelas is, however, greatly exaggerated by the antivaccinators. In the two periods already mentioned the infant mortality from erysipelas in England and Wales *decreased* by 16·7 per cent., whilst in Leicester, with neglected vaccination, there was an increase of 41·5 per cent. Similarly, diarrhœa and bronchitis have increased among the unvaccinated infants of Leicester more than in England and Wales as a whole, a fact which proves the fallacy of attributing them to vaccination.

With regard to cancer, the Royal Commission on Vaccination concluded: "There is not a shadow of evidence to connect the increase with the practice of vaccination, whilst there is . . . evidence pointing the other way." The same remarks are applicable to the alleged spread of leprosy by vaccination. There is no evidence, moreover, that tuberculosis has ever been inoculated by vaccination, and attempts to thus inoculate the skin of guinea-pigs with lymph from tuberculous patients have uniformly failed. That the disease may be transmitted through the medium of animal (calf) lymph is a groundless fear, which has been encouraged by antivaccinators. Such a case has never yet been reported, although animal vaccine has been in use for many years, more especially on the Continent. Moreover, tuberculosis in the young calf is exceedingly rare; and precautions will be taken to ascertain, either by the tuberculin test or by post-mortem examination, or

both, that the calf that is to be or has been employed is tuberculosis-free.

Certain rashes have doubtless been produced, and not infrequently, by vaccination. Even when vaccine quite pure and free from other virus is inoculated, eruptions of urticaria, erythema, lichen, purpura, and later, as sequelæ of vaccination, eczema, psoriasis, pemphigus, urticaria, and congenital syphilitic rashes, have been observed. When, however, the vaccine has not been pure, impetigo contagiosa, syphilis (very rare), erysipelas, cellulitis, pyæmia, and local gangrene, have resulted from the inoculation of the lymph.

It is the intention of the Government to limit vaccination and revaccination in the future, as far as is possible, to vaccination with glycerinated calf lymph. The object is to reduce the risks of conveying "vaccinal" diseases, which were incidental to "arm-to-arm" vaccination. The glycerine serves to preserve the lymph, without in any way interfering with its activity, and it destroys extraneous organisms (even, in time, the *Bacillus tuberculosis*). The presence of a little blood in the lymph is quite harmless, and the danger of imparting disease by the use of such lymph appears to be absolutely avoided.

The calves used are carefully watched, their past history is inquired into, they are slaughtered after use, and a post-mortem examination is made, whilst in some countries the calf is tested with tuberculin before inoculation with vaccine lymph. These precautions are taken notwithstanding the great rarity of tuberculosis in young bovines. The age of the calf, its general health and nutrition, and even the season of the year, affect the quality of the lymph collected. In this country sufficient lymph is collected on an average from every calf to vaccinate some 200 to 300 children.

In Paris the lymph is diluted with an equal bulk of glycerine; in Brussels twice the bulk of glycerine is added; in England five to eight times its bulk of 40 or 50 per cent. pure glycerine is added; and in Berlin a solution of equal parts of glycerine and boiled water is added to the epithelial pulp scraped from the vaccine vesicles, in the proportion of 14 parts of the solution to 1 of the pulp.

It is probable that if vaccination is performed on a person who has already contracted small-pox, within forty-eight hours of the exposure to contagion, vaccinia ensues and small-pox is avoided. But if performed at a later date small-pox is contracted, modified if within three days, but unmodified if later, with vaccinia possibly running its own course at the same time.

Considerable evidence has now been accumulated in support of the view that cow-pox is human variola modified by its occurrence in the cow. Klein has shown that when lymph from the vesicles of a human small-pox case is inoculated into a calf, very little local result is produced, but that if material from the local lesion is taken on the fifth day, and inoculated into another calf, and this process is continued until four calves have been inoculated, the material from the fourth calf (four removes from the small-pox patient) might with safety be transferred to the human subject, with the production of typical vaccinia. The lymph from the vaccine vesicles, so produced in the human subject, caused, alike on inoculation into the bovine or the human subject, typical vaccinia.

Whatever the original cause of cow-pox in the bovine species, it seems certain that the disease is now transmitted directly from animal to animal, and that its origin from human small-pox is an event of very rare occurrence, if it ever happens.

Scarlet Fever.

This is a specific infectious disease like small-pox, its propagation being dependent upon a specific contagium derived from a previous case of the disease, if we except its possible origin from a certain diseased condition of cows, and possibly other animals. The incubation period varies from a few hours to eight days, and is usually from twenty-four to seventy-two hours. Infection is given off in the throat secretions and from the skin of the patient during the whole period of illness, but the acute stage of the fever, when the sore throat and rash are most highly developed, is probably the most infectious, and not the desquamative stage, as once generally supposed. The contagion clings with great pertinacity to the clothes, bedding, and furniture of the sick-room, but is not capable of diffusion and dissemination through the air without loss of virulence, like the small-pox contagium appears to be. The usual duration of infectiveness in scarlet fever is from six to eight weeks, lasting throughout convalescence, and possibly prolonged by the occurrence of renal or other complications. In large towns, scarlet fever epidemics tend to recur every few years, as a fresh series of susceptible children become exposed to the contagion.

Scarlet fever is more especially a disease of childhood. The influence of age, sex, and season upon the incidence and fatality of the disease may be thus summarized:

The mortality from scarlet fever is greatest in the third year of life, and after this diminishes with age, at first slowly and afterwards rapidly. This diminution is due to—(1) the increased proportion in the population at each successive age-period protected by a previous attack; (2) the diminution of liability to infection in successive

age-periods of those who are as yet unprotected; (3) the diminishing risk in successive age-periods of an attack, should it occur, proving fatal. The liability of the unprotected to attack is small in the first year of life, increases to a maximum in the fourth or fifth year, and then becomes rapidly smaller and smaller with the advance of years. The chance that an attack will terminate fatally is highest in infancy, and diminishes rapidly with years to the end of the twenty-fifth year, after which a well-marked attack is again somewhat more dangerous. The female sex throughout life is more liable to scarlet fever than the male sex; but the attacks in males, though fewer, are more likely to terminate fatally.

The proportion of fatal cases to attacks of scarlet fever cannot be accurately stated, owing to the large number of unrecognised cases of very mild type, often without skin eruption, and with very little desquamation. If all such cases of infectious sore throat without eruption, which are by no means uncommon in adults or those who have been partially protected by a previous attack, could be included, the case mortality (proportion of deaths to attacks) would probably not be found greater than 2 or 3 per cent. These very mild and unrecognised cases are, doubtless, most frequent sources of dissemination of infection, and the fact of their being true scarlet fever cannot be doubted. The mortality of well-marked cases, such as those admitted into the Metropolitan fever hospitals (1892-9), is 4·9 per cent.; whilst the average mortality of notified cases in London (average of 1890-99) is 4·2 per cent.

For the ten years 1881-90, the death-rate from scarlet fever per 1,000 living at all ages was 0·33. Under five years the death-rate was 1·7 per 1,000; between five and

ten years it was 0·76 per 1,000, decreasing in the next quinquennium to 0·15 per 1,000. During the ten years 1871-80 the average death-rate in England from scarlet fever was 0·7 per 1,000 living at all ages.

The lower mortality from scarlet fever of recent years is due, not to a lesser prevalence of the disease, but to a milder type. The proportion of deaths to attacks is now only about a half of what prevailed twenty years ago.

Unlike small-pox in unprotected communities, scarlet fever is a disease from which very many people altogether escape. The importance of saving young children from attacks of scarlet fever has been well expressed by Dr. Whitelegge:

"In shielding a child against infection during the first few years of life there is a double gain; every year of escape from scarlet fever renders him less and less susceptible, until finally he becomes almost insusceptible; and, secondly, even if he should ultimately take the disease, every year that the attack is deferred reduces the danger to life which it brings. In other words, attacks of scarlet fever become both less severe and less frequent with every year of age after the fifth. Up to the fifth year the liability is less (than in the fifth year), but the risk to life in case of attack is very great."

The same reasoning applies with almost equal force to measles, whooping-cough, and the other infectious complaints of childhood.

Overcrowding and insanitary conditions in houses tend to aggravate the severity of scarlet fever attacks, and to aid in their dissemination, but can have no influence *per se* in originating an outbreak.

Scarlet fever is most prevalent and most fatal in the autumn, in the months of October and November.

Two curves may be formed, one expressing the weekly or monthly deaths as percentages of the average weekly or monthly mortality throughout the year (Fig. 83), the other expressing the number of weekly or monthly cases as percentages of the weekly or monthly average of cases throughout the year. These curves correspond very closely, but Dr. Whitelegge has noted that the mortality curve rises less and falls less above and below the mean than the case curve, which would imply that when most prevalent scarlet fever is least fatal, and *vice versâ*. There is, at least, a strong probability in favour of this view, as the number of mild cases is usually greatest when scarlet fever is most prevalent.

It sometimes happens that a patient discharged from hospital, apparently free from infection, is the means of communicating the disease to another member of the family on his return home. These "return cases" have been explained in many ways. Doubtless they are sometimes examples of mere coincidence; at others they may result from: (1) the non-disinfection of articles of clothing, books, or toys, which have been used by the patient prior to removal to hospital, and produced again on the patient's return home; (2) carelessness on the part of hospital officials in prematurely discharging patients with bad throats, ear discharges, etc., or in not sufficiently bathing the patients and shampooing the head prior to discharge; (3) the reappearance of desquamation (?), or infectious discharges after dismissal from hospital in an apparently healthy condition; (4) the conveyance of the infection in the lungs of recently discharged patients (?).

The entire prevention of such "return cases," even by the exercise of every possible care, seems impossible in

practice; but their number would doubtless be reduced if parents would observe the precaution, which they should always be advised to take, of keeping the child apart from other children for at least one week after returning home from hospital.

Measles.

A specific infectious fever, with an incubation period generally of nine to twelve days, but it may be as short as four days and as long as fourteen. The contagion is given off from the secretions of the nose, throat, and lungs, and from the skin of the patient during the whole period of illness; and the catarrhal stage preceding eruption is especially infectious. It is for this reason that epidemics of measles are so difficult to control. The infection is not widely diffusible in the air, but clings to clothes and garments.

Measles is a disease of infancy and early childhood, and is very fatal to young children, chiefly owing to the frequency of pulmonary complications and sequelæ. Adults unprotected by a previous attack are also susceptible, but the disease is so universal in this country that few children escape from it. The mortality from measles is greatest under three years of age; the highest death-rate is reached in the second year of life; after five years of age the mortality is enormously diminished. During the ten years 1881-90, the death-rate from measles averaged about 0·44 per 1,000 living at all ages; under five years of age the death-rate was 3·1 per 1,000, and between five and ten years only 0·27 per 1,000. In the ten years 1871-80, the average death-rate in England from measles was 0·38 per 1,000 living at all ages; and in the decennium 1861-70 it was 0·44. Both sexes are equally liable to

attack, and the case mortality is about the same for both. In this disease the case mortality, or proportion of deaths to attacks, is greatly affected by overcrowding and insanitary conditions generally. In the overcrowded houses of the poor, amongst badly nurtured children, the proportion of deaths to attacks may be as much as 20 or 30 per cent., and is, no doubt, intensified by the neglect of the parents to provide suitable warmth and nourishment for the sufferers from a disease which they think of little moment. In healthy houses, well-nourished children almost invariably make a good recovery.

Measles is most prevalent and most fatal in the winter months of November, December, and January; but it also tends to become somewhat intensified in the late spring (May and June): see p. 492, Fig. 83.

Measles epidemics tend to recur in large towns about every two or three years, with the fresh appearance of susceptible children; and since the disease is pre-eminently fatal in the first, second, and third years of life, it follows that if it can be so far discouraged by preventive measures as to acquire epidemicity only every fourth year, a large number of children will have passed the age at which the disease is most fatal, and many lives will be saved.

Some people advocate the compulsory notification of measles, and the arguments that have been adduced in favour of this measure are as follows:

It is claimed that compulsory notification furnishes early information of the first cases, and that notification is the best means of obtaining this information. This information would enable the following measures to be carried out: (1) the visiting of parents and guardians, and advising as to isolation and removal to hospital (where such a hospital exists); (2) the control of school attendances; and (3) the prompt detection (to be followed by closure)

of schools which are acting as foci for the dissemination of infection.

It has also been asserted that the notification of measles, and the measures resulting therefrom, would cause the public to regard the disease with more seriousness, and that it would encourage amongst the poor a more general medical attendance upon the sufferers.

Those who do not favour the compulsory notification of the disease maintain that, on account of the exceedingly infectious pre-eruptive stage of measles, the notification certificate would arrive too late to be of much value in the adoption of the measures necessary to protect others in the infected household. In most cases four days elapse (during which the infection is at its highest) before the characteristic rash makes its appearance, and another day at least would follow before the notification is received and acted upon. Prior to the rash the disease cannot be diagnosed, and all those who are susceptible have probably been fully exposed to the infection. This is the intrinsic difficulty which has to be faced in measures dealing with this complaint. Further, there is a great tendency among the poor to regard the disease as inevitable and trivial, and in consequence they do not recognise the desirability of isolation, nor do they consult a medical man in a large percentage of cases, unless grave symptoms supervene. In country districts the *majority* of the cases are not medically attended. Obviously, then, those cases which, occurring in small houses often crowded with other children, are the most potent for harm, would not be notified; and the notification of cases among the better classes, who have already called in a medical man and received the benefit of his advice, would form the bulk of the notifications received.

Efficient home isolation of infant sufferers from measles

in the dwellings of the poorer classes is generally impracticable; and without the means of offering hospital isolation, the compulsory notification of measles would be premature. But even if such hospital provision were made—and it would have to be on a very large scale to deal with even a proportion of the cases occurring in an epidemic—there would still be much difficulty found in inducing the parents to accede to the removal from home of children of such tender years as those who form the bulk of the sufferers from measles.

Certainly, if notification is to prove of service, every possible use must be made of the information it provides. Every infected household must be promptly visited; the source of infection traced; the existence of unnotified cases discovered, if possible, from the clues afforded by the notified cases; schools, libraries, etc., must be communicated with; premises must be disinfected; and suitable isolation at home insisted upon (where possible). Now, all this would entail a large staff, which could scarcely be appointed temporarily with advantage; and if, therefore, notification proved a failure, it would be a very costly one.

During the past six years a few (under 1 per cent.) of the sanitary authorities in England and Wales have included measles in the list of notifiable diseases; and in the majority of cases the Medical Officers of Health either candidly acknowledge that they have reaped no advantage, and that the measure is a useless one, or they express their doubts as to its utility.

It is both interesting and significant to note that, up to the commencement of the year 1899, the Infectious Diseases Notification Act has been extended to measles in 110 cases, to rötheln in seven, to whooping-cough in twenty-six, and to chicken-pox in eight (on account of

the frequency with which it is confused with modified small-pox). But in thirty-eight of these cases the sanitary authorities have subsequently revoked the addition of measles, in one that of rötheln, in seven that of whooping-cough, and in four that of chicken-pox, while in one case the Act was extended to measles only for a limited period, which has now expired.

It may be useful to bring measles under the Notification Act in rural districts and in small isolated communities, if in these cases every advantage is taken of the information thus obtained to detect unnotified cases, and the means of hospital isolation are provided; but in larger communities, especially when not adopted in neighbouring districts, the measure is not to be recommended.

What has to be faced is a largely preventable mortality due to ignorance—a mortality which is very high among the poor, and very low among the better classes; and the most successful scheme for reducing measles mortality appears to be one which will take advantage of all the means which elementary schools offer of (*a*) educating the future parents, and of (*b*) gaining early information, and checking the spread of infection.

The greatest checks to the spread of the disease would be the exclusion from school of children from infected houses, the sending home of suspicious scholars, the visitation of absentees, the notification of infected households to school attendance officers, and the occasional closure of schools during epidemic periods.

It is highly desirable that measles should be brought within the scope of the expression "infectious disease" as used in the Public Health Acts of 1875 and 1891 (London), in so far as relates to wilful exposure of sufferers, and to the prohibition of the use of public

vehicles for conveying measles cases, unless certain precautions are taken.

Rötheln, Rubella, or German Measles.—This is a specific infectious fever, propagated by a specific contagium, and not a hybrid between measles and scarlet fever, from either of which diseases it is entirely non-protective. It has a usual incubation period of fourteen to eighteen days, but may vary from one to three weeks, and is infective during the whole course of illness (seven to fourteen days). It is not a disease of common occurrence, and the illness produced is almost invariably very mild. It is probable that children and young adults are most susceptible.

Whooping-cough.

This is a specific infectious disease, the infection being given off in the secretions from the lungs. The specific organism has not yet been determined. It is probably not carried far in the air, but clings pertinaciously to articles of clothing. The period of incubation may last from one to three weeks, and the period of infectiveness is usually not less than six weeks from the onset of cough, and may be longer.

Infants and young children are especially susceptible, and comparatively few escape attack. The younger the child, the greater is the likelihood of the attack proving fatal; 40 per cent. of the mortality from whooping-cough occurs in the first year, 30 per cent. in the second, 15 per cent. in the third, and 6 per cent. in the fourth. Girls suffer more from severe attacks which end fatally than boys, and their liability to contract the disease is also probably greater. In the first two years of life the proportion of deaths to attacks cannot be less than 10 per cent., and is probably higher. After the third year this

proportion is not more than 2 per cent. Adults seldom suffer, as the protection afforded by an attack in childhood is so universal; but if unprotected they are equally liable with children.

Whooping-cough is now the most fatal of all the infectious complaints of childhood under the age of five years. For the period 1881-90, the death-rate was 3·4 per 1,000 under five years of age (measles being 3·1); and the death-rate for all ages was 0·45 per 1,000. Between 1871 and 1880 the death-rate for all ages averaged 0·5 per 1,000.

Whooping-cough occurs in regularly recurring epidemics every few years, but it has an exceptional prevalence and fatality in the spring. The seasonal curve attains its maximum late in March or early in April, and from that point rapidly declines (see Fig. 83).

Typhus.

A specific contagious disease, but almost invariably found to be associated with conditions of filth and overcrowding in large towns amongst poor working-class populations.

The usual period of incubation is about one to two weeks. The infection is contained in the exhalations from the lungs and skin, and is transmitted through the air from the sick to the healthy; but it is rapidly destroyed by dilution with fresh air, and does not cling to articles of clothing, so that in a well-ventilated house typhus rarely spreads from the original case. The female sex and the age-period of ten to twenty-five years appear the most susceptible.

Being so closely associated with overcrowding, typhus increases in intensity during cold weather, when there is an inducement for many people to huddle together to

keep warm. In some of our large towns, epidemics recur in certain poverty-stricken quarters with considerable regularity, as fresh susceptible cases arise.

The mortality from typhus has undergone an enormous diminution in this country during the last twenty years. Before 1869, typhus, enteric fever, and simple continued fever were included together in the Registrar-General's returns under the generic heading of "Fever"; but since that date mortality returns of these three diseases have been presented separately. In 1869 the death-rate from typhus in England was 0·193 per 1,000 living at all ages; between 1881 and 1890 the average typhus death-rate was only 0·014 per 1,000; between 1886 and 1890 the average rate was only 0·0066 per 1,000; that is to say, it has fallen to one-thirtieth of its former rate in the space of twenty years.

Simple continued fever is, probably, in a large majority of cases, a convenient term for the registration of deaths due to undiagnosed and obscure cases of fever, such as may occur in typhus, general tuberculosis, septicæmia, pneumonia, and intermittent fever. Dr. Longstaff is of opinion that only a very small proportion of these deaths, if any, are due to enteric fever. Simple continued fever as a cause of death exhibits a decrease in the last twenty years closely analogous with that of typhus (in 1869 the death-rate was 0·24 per 1,000; in 1890 the death-rate was 0·013). This decrease is, no doubt, largely due to greater precision in diagnosis, but may to a certain extent be due to the diminishing prevalence of a definite disease.

Diphtheria.

The etiology of this disease is still to a certain extent veiled in obscurity. Whilst on the one hand it cannot

be doubted that diphtheria is contagious, the contagion being transmitted from the sick to the healthy, on the other hand diphtheria outbreaks in rural districts at times appear to originate independently of the infection of a pre-existing case, and to be causally related with the effluvia arising from decomposing animal and vegetable substances, or with excessive moisture of soils or sites of houses. But recent research seems to show that the diphtheria contagion has the power, under certain conditions, of lying latent for long periods of time, with the capacity of renewing its virulence under special circumstances, and that, as in the case of enteric fever, mild and unrecognised forms of the disease may deposit the virus in the most unlikely localities.

Diphtheria occurs endemically in certain localities, localized epidemic extensions taking place from time to time. It has been a matter of observation that certain rural districts, in which the surface soil is cold and humid, and where damp houses and privy and drainage nuisances abound, or where the aspect involves much exposure to cold, wet winds, are particularly favoured by diphtheria. The broad geological features of a district—the permeability or otherwise of the surface strata—have not, as such, any observed influence on the development and diffusion of the disease; but such topographical relations as facilitate the retention of moisture and organic refuse in the surface soil, or involve bleakness of site and exposure to cold and wet winds, appear to be of importance.

Until lately diphtheria was regarded as being to a far greater extent a rural than an urban disease, but during the last ten years diphtheria mortality has progressively increased very greatly in London and other large cities. Thus, in 1881 in London the death-rate from diphtheria

was 0·17 per 1,000, the average of the ten years 1871-80 being 0·12 per 1,000. The average of the decennium 1881-90, however, was 0·26 per 1,000; and in 1889 the death-rate was 0·39 per 1,000—a mortality three times as great as that prevailing in the 1871-80 decennium. The average death-rate of the ten years 1890-99 is 0·49 per 1,000. The death-rate in the twenty-eight large towns has also increased from 0·14 in 1881 to 0·26 in 1889, although the death-rate from this disease in the country generally has only risen from 0·12 in 1881 to 0·18 in 1889. As to the distribution of the disease in England and Wales, it is most prevalent and fatal in the counties of Essex, Kent, Middlesex, Sussex, Surrey, and Suffolk, and also in South Wales, and least prevalent in the counties of Nottingham, Northampton, and Cumberland. There can be little doubt that to the system of compulsory elementary education now prevailing in our large towns, which gives such extended facilities for the spread of infection amongst young children, some of this increase must be attributed. It is possible, however, that some small portion of the increase in the fatality of diphtheria is apparent, and not real, owing to the greater precision in diagnosis, and to the consequent registration of cases as diphtheria which would formerly have been certified as due to croup, laryngitis, or tonsillitis.

The incidence of the disease is most marked in children between the ages of two and twelve years, and subsequently decreases with every year of advancing age. As a rule, the younger the child, the greater the chance of an attack proving fatal. The average mortality of cases notified in London (average of 1890-94) was 23·8 per cent., and is now 17·2 per cent. (average of 1895-99, during which years antitoxin has been in use). The case mortality in the Metropolitan Asylums Board hospitals

was 30·3 per cent. (average of 1888-94), and is now 17 per cent. (average of 1895-99).

School attendance is now acknowledged to be a very potent factor in the spread of diphtheria, as in scarlet fever and measles. Infection is spread by the attendance at school of mild or unrecognised cases, and this is especially likely to occur in the public elementary schools, where the class-rooms are often overcrowded and badly ventilated, and the children are brought into very close contact at the most susceptible age periods. Mr. Shirley Murphy has shown that in London the increased incidence of diphtheria among children from three to ten years of age (school age) first became conspicuous in the year 1871—the year, that is, in which the Elementary Education Act first became operative, that there is a marked decline in incidence during the holidays, and a subsequent rise with the re-opening of the schools (due allowance being made for the incubation period and for some delay in notification). Although during the summer holidays there is also a decline in incidence among persons over ten years of age, it is never so great as the decline among children of the school age (three to ten).

Prevalences of recognised diphtheria are very commonly associated in their beginnings, during their continuance, and after their apparent cessation, with a large amount of ill-defined throat illness; and there is considerable evidence in favour of the view that attacks of so-called "sore throat" exhibit, under certain favouring conditions, such as the overcrowding of children of susceptible age in dormitories and class-rooms, a "progressive development of the property of infectiveness," culminating in a definite specific type, which is indistinguishable from true diphtheria (Thorne Thorne). That is to say, in these forms of sore throat a virus is gradually

propagated by personal infection which is ultimately able to originate specific, and possibly virulent, diphtheria.

Diphtheria epidemics are occasionally inextricably mixed up with outbreaks of scarlet fever and measles. There is no reason to believe that diphtheria is in any way interchangeable with scarlet fever or measles, in the sense that the infection of the one disease may produce the other; but it would seem that the morbid condition of the throat left after scarlet fever or measles predisposes the sufferer to become receptive of the diphtheria contagion, which may be present in a locality together with the poison of either of the other diseases. Faulty sanitary surroundings (drainage and filth nuisances) tend to the production of diphtheria in the same way, namely, by engendering a morbid condition of the tonsils favourable to the growth of the diphtheria contagion if implanted thereon.

Patients convalescing from scarlet fever are not infrequently attacked with diphtheria ("post-scarlatinal diphtheria"), the infection of which is probably introduced into the scarlet fever wards by an unrecognised case of diphtheria. The prevention of post-scarlatinal diphtheria is a matter of great difficulty. A bacteriological examination of the throats of all cases on admission would prevent the introduction into the fever wards of cases of diphtheria running concurrently with scarlet fever, but might not lead to the isolation of patients in the incubation stage of diphtheria.

The diphtheritic contagion is given off from the body in the secretions from the mouth, nose, and throat, and, although probably not far diffusible in the air, clings with great pertinacity to infected articles of clothing and bedding.

As is the case with some other infectious maladies, there

appears to be in certain individuals a peculiar hereditary or family susceptibility to attacks of diphtheria. A still more remarkable circumstance is that in certain individuals, who have suffered once from diphtheria, there seems to be the possibility of the recrudescence of an infective quality attaching to ordinary attacks of sore throat (Gresswell). In such persons there is often chronic tonsillar and nasal inflammation, liable to become acute from chill or exposure, and then apparently capable of propagating true diphtheria.

Season has a marked influence on the manifestation, and, above all, on the mortality from diphtheria. Epidemic prevalences of the disease commonly commence in September, reach their highest point during October and November, and then subside slowly during the following two months—the smallest amount of mortality being witnessed in the summer—May to July. There is some excess of diphtheria mortality in females as compared with males. It is probably due, at all periods of life, to greater opportunity of exposure of females to infection (Thorne Thorne). The incubation period is usually under four days' duration, rarely, if ever, less than two or more than seven days.

An affection of the throat, in many respects similar to human diphtheria, has been noticed as occurring in cats, pigeons, fowls, and other birds, during periods of epidemic prevalence of this disease. According to Klein, diphtheria is a natural disease in the cat, which causes intense broncho-pneumonia and fatty degeneration of the cortex of the kidneys. The exudation in the bronchioles and air cells of the inflamed lobules bears a striking resemblance to human diphtheritic membrane, and in this exudation the *Bacilli diphtheriæ* are found present in large numbers. A very similar disease can

be produced in cats by subcutaneous inoculation of cultures of this bacillus, giving rise at first to a tumour at the seat of inoculation, subsequently followed by broncho-pneumonia and kidney degeneration. But the bacillus is only recoverable from the tumour, and is not found in the blood or affected organs, pointing, as in man, to the visceral disease being a result of the action of a chemical poison—an albumose—produced by the bacillus at the seat of inoculation and absorbed from thence into the system. It is quite possible, then, that some of the domestic animals which live in close association with human beings may be a means of propagating the disease.

There is abundant evidence to show that diphtheria has often been conveyed through the medium of milk, and this infectivity of the milk has been ascribed on some occasions to some morbid condition of the cow or cows. Klein has shown that cows and calves, when subcutaneously inoculated with cultures of the *Bacillus diphtheriæ*, develop a disease similar to that observed in cats, and usually proving fatal in the course of two or three weeks, the chief post-mortem signs being intense broncho-pneumonia and necrotic patches in the liver. But in addition these animals develop on the fifth day from inoculation an eruption on the udders and teats—papules passing into vesicles and pustules, which dry up into crusts—lasting five to seven days. The remarkable fact about this disease in the cow is that, unlike the human and cat disease, the bacillus passes into the system, for pure cultivations of it were obtained not only from the udder lesions, but also from milk taken from a teat unaffected by the eruption. This bacillus when inoculated into calves proved its infectious nature by causing a disease similar to that of the cow from

which the bacillus was taken, but attended also with fatty degeneration of the kidneys.

There is little or no evidence pointing to the spread of the disease by drinking contaminated water. Klein, indeed, has stated that the *Bacillus diphtheriæ* is killed when kept for a few days in pure water, on account of not finding sufficient nutriment.

In practice it is most important to recognise the disease at its very earliest stage, for if the bacillus is allowed time to form a sufficient dose of poison, it is useless to remove the diphtheritic membrane, as, though the bacilli may then be destroyed, sufficient poison may have passed into the system to cause the death of the patient. For in diphtheria, contrary to what occurs in most other infective maladies, the infection is not produced by the invasion of the tissues by a microbe, but by the diffusion through the organism of a toxin prepared on the surface of a mucous membrane, and therefore practically outside the body.

The specific bacillus may persist in the mouth for a considerable time after the false membrane has disappeared. Dr. Hermann Biggs (New York Health Department) has subjected 405 cases of true diphtheria to repeated bacteriological examinations during the course of the disease, and during convalescence. In 245 cases (60·5 per cent.) the Klebs-Loeffler bacillus disappeared within three days of the complete separation of the false membrane; in 103 cases (25·4 per cent.) the bacilli persisted for seven days; in thirty-four cases (8·4 per cent.) for twelve days; in sixteen cases (4 per cent.) for fifteen days; in four cases (1 per cent.) for three weeks; and in three cases (·75 per cent.) for five weeks, after the time when the exudation had completely disappeared from the upper air-passages. In many of these cases the patients

were apparently well many days before the infectious agent had disappeared from the throat. Such results as the above are suggestive of a method of dissemination of the disease by the mixing of convalescents with healthy people, whilst their throat secretions still contain specific bacilli. It is never safe to allow recovered patients to mix with healthy people until at least fourteen days have elapsed since the disappearance of all membrane. During the whole of this time the mouth and throat should be repeatedly washed with disinfectant lotions.

Outside the body the diphtheritic virus retains its active properties for long periods (many months), especially when deprived of air and protected from light. The action of light and air and alternating moisture and dryness destroy the virus with considerable rapidity. The bacilli can resist a dry heat of 98° C. for one hour, but a moist temperature of 58° C. is sufficient to kill them, so that boiling water or disinfection in a steam chamber is always perfectly efficacious in destroying their vitality.

The virus of diphtheria attenuated as to its virulence by exposure to atmospheric conditions is, no doubt, very widely distributed among populous communities. The attenuated bacilli very readily regain their virulence when they become implanted on human fauces weakened by the attacks of other organisms, especially erysipelas streptococci, and the organisms associated with measles, scarlet fever, and rötheln, as well as of those occasionally present in drain and sewer emanations (drain throat).

It is probable that the Klebs-Loeffler bacillus may be much more widely distributed in the throat secretions of children than at one time was considered possible. In large towns, when diphtheria is endemic, it would appear from recent statistics that from 5 to 10 per cent.

of the children of the working classes have the bacillus in their throats; and in the majority of these cases there is no evidence of any unhealthy condition of the fauces.

An antitoxin serum has recently been introduced through the observations of Behring, Kitasato, and others, which not only has the power of conferring immunity upon animals, but also of arresting the disease after it has commenced in the human subject. The serum is obtained as follows: The virulent Klebs-Loeffler bacillus is grown in broth for three or four weeks, when a sufficient quantity of toxin will be furnished in the liquid by the metabolism of the bacilli. The culture liquid is then filtered through a porcelain filter, to arrest all microbes, and the clear liquid resulting is injected subcutaneously into a horse. Gradually, by repeated injections of this toxin over a period of two or three months, the horse is brought into a condition in which its serum possesses very high antitoxic properties. The animal is then bled, and the serum obtained from the drawn blood is stored, and ready for use.

That the lessened case mortality from diphtheria which has resulted from the use of antitoxin is not attributable to any natural attenuation of the virus, or to a change in the conditions of environment, is proved from the fact that in parts of Germany and elsewhere on the Continent, whilst the local incidence of the disease has remained unchanged among people in the same community, and influenced by similar sanitary environments, there is a reduction in the case mortality only among those who have been treated with antitoxin.

In order to facilitate an early application of the remedy, some local authorities keep a stock of antitoxin at their public offices, and supply it to practitioners at cost price, since they are not empowered to incur the expense of

gratuitous provision of what is essentially a curative remedy. The provision is a useful one, for experience has shown the high importance of the early application of a large initial dose, ranging from 2,000 to 3,000 units, according to the gravity of the symptoms.

Asiatic Cholera.

Cholera is endemic in the delta of the Ganges, and probably also in other parts of India and the Orient. Epidemic extensions take place from time to time, the disease being imported from these "homes of cholera" into far-distant countries, by sea or overland, by means of persons suffering from or recovering from it, or possibly by means of infected articles.

The usual mode of propagation of cholera is through drinking water. The specific poison is contained in the copious bowel discharges of the sick, and may find its way through the soil on which the dejecta are thrown, into streams, wells, or tanks. It is also possible that the contagion is at times transmitted through the air by the dried choleraic discharges being borne into the air by currents of wind. Temperature and moisture are controlling factors of great importance. When the disease is imported into a temperate climate, the intensity of the epidemic is invariably felt in the late summer and autumn, and dies away with the approach of cold weather, possibly to again acquire epidemic intensity in the following summer. It is evident, therefore, that the specific virus can only attain its virulence where the temperature of the air, and therefore of the soil, is sufficient. The combination of moisture and heat of soil, characteristic of the Ganges delta, appears to offer the most suitable environment for the cholera virus.

Surgeon-Major Cunningham has shown that the comma

bacilli, which are found in the evacuations of cholera patients, and which are regarded by many as the specific cause of the disease, when introduced into polluted water or soil, tend rapidly to disappear, as they are attacked and destroyed by the saprophytic bacteria always present in such circumstances. The comma bacillus may be regarded, however, as pathognomonic of the disease; and its presence when detected in the stools may be considered as sufficient to establish the diagnosis of Asiatic cholera.

The incubation period of cholera is usually very short —one or two days; but it may occasionally be prolonged for ten days or more. The evacuations are most infective during the height of the disease; and it is believed that the specific virus (bacilli) may multiply, after leaving the body, in water or soil of suitable temperature.

In epidemic periods the proportion of deaths to attacks is greatest during the period of maximum intensity of the epidemic. When the epidemic is first commencing, and after it has begun to subside, the recoveries may considerably exceed the deaths in number.

The three main routes which cholera has taken from the endemic area in India to Western Europe are as follows: (1) Through the north-western provinces of India to Afghanistan, and thence by caravan routes to Khiva and Russia; (2) from Southern India up the Gulf of Persia, and thence to Syria and Egypt, and across Persia to the Caspian Sea; (3) mainly by pilgrim traffic to the Red Sea ports and Egypt, and thus to the Mediterranean.

The preventive measures which have hitherto acted most successfully in keeping the disease out of these islands have reference to our "first line of defence," *i.e.*, the coast. By far the most important are contained in

the provisions of the Cholera Order of the Local Government Board (*quod vide*), but other valuable measures have been: (1) The Order prohibiting the importation of rags from all infected ports; (2) the Order prohibiting the landing of "filthy and unwholesome aliens," unless they first satisfy the medical officer of health of their freedom from cholera, and give their names and destinations; (3) the provision of the means of isolating the infectious sick at our ports; (4) the placing of these ports in a good sanitary condition by dealing with insanitary dwellings and areas, so as to remove, as far as possible, all foci for infection; and (5) the adoption of every possible precaution to safeguard the purity of the public water-supply.

The issue of printed notices by the local authority, in which instruction is given as to the means to be adopted by the individual to guard against infection, is a useful measure. In such handbills it should be stated that raw vegetables and fruit should be avoided; that extreme cleanliness in the household should be adopted, since cholera is essentially a filth disease; that all milk and water should be boiled shortly before use; and that on the occurrence of diarrhœa in any individual, medical advice should be at once sought.

When the danger of an outbreak becomes imminent in any district, a staff of nurses should be enlisted, arrangements made for the use of any available buildings as temporary hospitals, a large stock of disinfectants provided for gratuitous distribution, and measures taken for the supply of anticholera inoculations to medical practitioners.

The provisions of the Cholera Order have supplanted those of Continental quarantine in these islands, and are doubtless far more successful. The facts which tell against the efficiency of quarantine, as practised elsewhere, are certainly sufficiently strong to warrant the

adoption by all countries of the English system. The detention of persons on board an infected ship for many days is not a measure calculated to protect the healthy from infection, and to limit the spread of the disease, whilst the delays thus caused are ruinous to trade. Such measures have been shown to be unnecessary in this country, and, owing to frequent evasions, they often fail in their object of keeping the disease out of foreign ports. In Malta the provisions of Italian quarantine continue to be practised, but the British system is in application at Gibraltar; the result is that Gibraltar generally escapes, whereas Malta almost invariably suffers. A very vigorous system of quarantine, moreover, utterly failed to prevent cholera crossing the great natural barrier afforded by that huge inland sea, the Caspian, when the disease appeared on its eastern shores on the occasion of the last great visitation of cholera to Europe.

Land quarantine—by which is implied the drawing of a cordon of soldiers or police round an infected area—generally also fails in its purpose.

Enteric Fever.

Typhoid or enteric fever, excepting its possible origin from a cow disease, is a specific disease dependent for its propagation upon a specific virus. It is not always possible to establish the dependence of an outbreak on a pre-existing case; but it is not necessary for this reason to assume that the disease can originate independently—from decomposition of organic filth apart from the infection of a previous case—seeing that the contagion may undoubtedly have a long period of latency with diminution or loss of virulence, which can again be roused into action under special but unknown combinations of circumstances. Besides this, enteric

fever is often a mild disease and unrecognised even by the patient himself, who goes about his ordinary avocations unaware that he is spreading contagion broadcast.

The period of incubation is usually a long one, from ten to fourteen days. The limits of its maximum duration are not accurately known, but in rare cases it is prolonged to twenty-one days. The infection is contained in the stools, and possibly in the urine, during the whole period of illness (four to eight weeks or longer); and the virus, which is probably the bacillus isolated by Eberth and Gaffky, is transmitted from the sick to the healthy, chiefly by means of drinking water, but occasionally through fomites and the air. In enteric fever, as in cholera, it would appear probable that at the moment of leaving the body the specific contagion is not possessed of any high degree of virulence, for the reason that the mode of existence of these organisms in the intestine must be from the first practically an anaerobiotic one. Probably many people who are exposed to the infection of both enteric fever and cholera escape, owing to the virus being destroyed on swallowing by the acid of the gastric juice. But those who are out of health, or who are suffering from diarrhœa (especially is this the case in cholera), may offer much less resistance to the invasion of the contagion.

Enteric fever is not a disease of universal occurrence like small-pox formerly was in unprotected communities. Many people appear to be insusceptible to the infection; but of this a partial explanation is offered by the above-quoted remarks, and by the possibility that the disease may have been contracted in childhood, when it is often mild and unrecognisable, and that, as a rule, one attack confers immunity for the remainder of life. No age and

neither sex is free from risk of attack, but the period of fifteen to twenty-five years appears to be specially prone to suffer. Between the age of three and twenty years the mortality of females from enteric fever is greater than that of males. This higher death-rate at these ages is due, not to a greater liability on their part to contract the disease, but to a higher case mortality, *i.e.*, a larger proportion of attacks proving fatal.

During the period 1871-80 the mortality from enteric fever in England and Wales was at the rate of 0·32 per 1,000 living at all ages; but the death-rate from this disease has undergone for a long period, and is still undergoing, a steady and sensible diminution year by year. In 1869 (the first year in which enteric fever returns, as separate from "fever," are obtainable) the death-rate was 0·39 per 1,000, whilst in 1890 the death-rate was only 0·18 per 1,000, a reduction of more than half. The average death-rate for the ten years 1881-90 was 0·2 per 1,000. This result may be attributed to the improvements in water-supply, sewerage, and domestic sanitary arrangements, throughout the country generally, that have been so marked a feature in the social progress of the latter half of this century.

The proportion of deaths to attacks in enteric fever cannot be accurately stated, owing to the number of mild cases that escape recognition. In typical cases the mortality varies from 15 to 25 per cent. of the attacks. The average mortality of cases notified in London (average of 1890-99) is 18·3 per cent. In early life the type of the disease is less severe than in adolescence and adult age.

Enteric fever is most prevalent, and causes the largest number of deaths, in the late autumn. The seasonal mortality curve (see Fig. 83) is seen to rise in August,

and attain its maximum late in October or early in November, from which point it gradually falls. In our large towns a hot and dry summer often tends to aggravate the intensity of the autumnal rise; and this fact, together with its special seasonal prevalence, appears to point to a high temperature being necessary for the proper development of the specific poison in polluted soils, etc., and for the attainment of its greatest degree of virulence. It must be remembered that the earth at a few feet from the surface heats much less rapidly than the air, and that the highest annual temperature in the soil is not attained until late in the summer or early in autumn.

It is now established that the infection of enteric fever may be conveyed in shell-fish, more especially in oysters, mussels, and cockles, which are collected from tidal waters where the water is liable to considerable pollution from sewage; and it has been shown that the specific bacilli of enteric fever and of cholera are capable of existing in sea-water for many weeks. Legislative measures are therefore required in the interest of public health to prohibit the laying down of oysters in dangerous localities; and to that end all oyster-layings, fattening beds, and storage ponds should be made registrable after approval by the sanitary authority, and also subject to frequent inspection. Section 4 of the Infectious Diseases (Prevention) Act, 1890, which enables authorities to prohibit the supply of milk which is causing, or is likely to cause, disease, might also, with modifications, be made to apply to oysters and other shell-fish. The public should, moreover, be guarded against the importation of infected oysters from abroad.

In the later stages of the disease the typhoid bacillus may be present in large numbers in the patient's urine,

and this fact shows the necessity of invariably treating the urine with the same precautions as the fæces.

There are good grounds for belief that "the virulence, and even the specific quality, of an organism may be a matter of progressive development according to soil and surroundings" (Thorne Thorne). Support is given to this theory by the behaviour of diphtheria, enteric fever, and cholera, in some of their epidemic manifestations; and it is noteworthy that in enteric fever and in cholera an outbreak is often preceded by cases of "diarrhœa," which may be instances of the mild or "ambulatory" type of the disease.

In hot countries, where flies abound in enormous numbers, it is probable that enteric fever is very frequently transmitted through their agency, the flies directly conveying the contagion on their feet from infected excreta to some article of food.

It is the experience of numerous localities that enteric fever may be endemic notwithstanding a water-supply of undoubted purity. In these localities—generally poor and crowded—there are sanitary circumstances which generally conduce to soil pollution, such as defective house and yard drainage and sewerage, unpaved or badly paved yards around houses, allowing refuse to pollute the soil, and, above all, defective privy middens containing considerable accumulations of excreta, much of the liquid part of which finds its way into the soil. Many observers have ascertained that the incidence of the disease is always heavier on houses with dry closets than on those with water-closets; and, among the former, those with middens are more frequently infected than those with pails, the difference being more marked the poorer the class of houses (Boobyer). The explanation of these circumstances is found in the now established

fact that the *Bacillus typhosus* will remain alive in soil containing organic matter for many months; and when the conditions of soil temperature and surface moisture are favourable, there is a marked multiplication of the bacillus, under favourable circumstances the growths surviving even from one summer to another. These facts have been recently proved by the experiments of Sidney Martin and Robertson.

That the disease is frequently communicated by personal intercourse is repeatedly demonstrated by its spread to those in attendance on a patient in dwelling-houses, and even in hospitals.

The numerous outbreaks in which the disease has been shown to be conveyed through the medium of drinking water, point to the necessity of exercising a constant supervision and sanitary control over all sources of drinking water, both by the establishment of protected areas around the sites from which water is collected for drinking purposes, and also by systematically ascertaining the degree of purity of the water by means of repeated chemical and biological examinations.

Pettenkofer has shown that in Munich there was a remarkable correspondence between the rise of the subsoil water and the decline in the prevalence of enteric fever, and *vice versâ*. He does not profess to explain this relationship, but considers the movements of the ground-water were an invariable index to the extent of enteric fever incidence in Munich.

The serum diagnosis of enteric fever (Widal) is an important means of aiding the clinical diagnosis of the disease; and since it is in the public interest that the diagnosis should be prompt and certain, in the case of a disease which so often has a masked and insidious onset, many sanitary authorities now provide medical

practitioners with a so-called "diagnosis outfit," containing a small capillary tube for collecting and sealing up some of the blood of a suspected patient. The blood is returned to the local offices, where arrangements are made for testing it at the public expense. The diagnosis outfit also comprises a sterilized swab in a tube for collecting suspected exudation or membrane from the throats of patients thought to be suffering from diphtheria. Similar provisions have also been made in some districts for enabling medical practitioners to avail themselves of the bacteriological diagnosis of tuberculous sputum. Such diagnoses add definiteness to administrative procedure, *quâ* isolation, disinfection, and the admission of patients to hospital wards.

The evidence so far recorded of Widal's test establishes the fact that the reaction of the blood on the *Bacilli typhosus*, causing a characteristic clumping of the latter, and a total arrest of motion within a definite time limit, may be delayed, or occasionally may not be obtained in cases of genuine typhoid infection; and also that it may in some instances occur in non-typhoid cases, though not in an intense degree. The average of successes in diagnosis approximates, however, to 95 per cent.

In carrying out this method of diagnosis, all that is necessary is to collect a small quantity of blood from the finger of the patient in a capillary tube, allow it to clot, transfer the serum to a "sedimentation" tube in which it is mixed with an equal quantity of an emulsion of the specific bacteria, and watch the result as to agglutinization and immobilization of the bacteria (Wright). This method of serum diagnosis is still in its earliest experimental stage, but when duly authenticated it will probably be found useful not only for the diagnosis of the disease after attack, but also for ascertaining whether

a particular individual is susceptible to attack. It has already been shown that the blood of persons who have been submitted to protective inoculations with sterile cultures of typhoid bacilli in broth (antityphoid vaccines) is in some measure antagonistic to the virulent typhoid bacillus, as the serum has the power of immobilizing and agglutinating the bacillus; and if this is the case, it will probably be found that the blood of those persons who are naturally immune to enteric fever will present the same characteristics. The serum diagnosis, then, will probably be found of great utility in the indications it gives for antityphoid vaccinations in the case of young recruits proceeding to India or other countries where enteric fever is very prevalent.

Dysentery and Diarrhœa.

Diarrhœa is, of course, merely a symptom of very many diseases. But in the sense here understood it means those acute specific attacks of illness of which the diarrhœa is the most prominent symptom, which occur so generally in persons of all ages, but more especially in infants and young children, towards the middle or close of a hot dry summer. The death-rate from diarrhœal complaints remains remarkably constant through the winter and spring, but with the onset of hot summer weather in many large towns an extensive outbreak occurs, the chief incidence of which falls upon those at the two extremes of life, or who are enfeebled in health. The diarrhœa is in many cases of a choleraic nature, accompanied by cramps, spasms, and signs of collapse, and appears to be due to consumption of tainted food, or of impure water, or to the breathing of fouled air. The putrefactive changes which occur in food and fouled water or soil are all more rapid and intense under the

influence of a high temperature ; and it is quite reasonable to believe that many of these diarrhœal attacks are due to the action of the bacterial agents of putrefaction, or of their products, when taken into the system.

Many different terms are employed to designate the disease officially known as "epidemic diarrhœa," and this fact leads to great difficulties in classifying death-returns. The terms employed include diarrhœa, epidemic diarrhœa, dysentery and dysenteric diarrhœa, intestinal (or enteric) catarrh, gastro-intestinal (or gastro-enteric) catarrh, gastro-enteritis, muco-enteritis, and gastric catarrh. This confusion of terms leads to much discrepancy in the classification of death-returns amongst different medical officers of health ; and early in 1900 the Royal College of Physicians authorized the use of the term "epidemic enteritis," or, if preferred by the practitioner, "zymotic enteritis," as a synonym for epidemic diarrhœa, and recommended the entire disuse of the other terms mentioned above.

Dysentery arises in a very similar way, and is probably merely an accentuated form of the disease with a tendency to become chronic, incidental to a tropical climate. The effect of chilling of the body, on which so much stress has been laid, is probably to increase the susceptibility of the system to the poison. Attacks of dysenteric diarrhœa, with discharges of blood and mucus *per rectum*, are occasionally associated with outbreaks of diarrhœa in this country.

Although it is unquestionable that dysentery and acute diarrhœa in the vast majority of cases appear to arise *de novo*, independently of the contagion of a previous case, yet it is also certain that the diarrhœal evacuations help to spread the disease in certain instances. It is not impossible that the diseased process may originate a

specific poison within the body, which on evacuation has an infective virulence not inferior to the enteric fever or cholera poison.

From the seasonal curve for diarrhœa it appears that the mortality begins to increase about the middle of June, rises rapidly to its maximum at the end of July or early in August, and falls somewhat less rapidly throughout August, September, and October. The following is a very brief epitome of Dr. Ballard's observations :

The summer rise of diarrhœal mortality in the large towns does not commence until the mean temperature recorded by the earth thermometer, placed 4 feet below the surface, has attained somewhere about 56° F.—no matter what may have been the temperature previously attained by the atmosphere, or recorded by the 1-foot earth thermometer. The maximum diarrhœa mortality of the year is usually observed in the week when the 4-foot earth thermometer attains its mean weekly maximum. The diarrhœa mortality declines with the 4-foot earth thermometer, and this decline takes place very much more slowly than that of the atmospheric temperature or of the 1-foot earth thermometer, so that the mortality from epidemic diarrhœa may continue long after the air temperature has fallen, even into the fourth quarter of the year.

The earth temperature at a depth of 4 feet is valuable as a measure of the cumulative effect of the sun's heat, the variations in earth thermometers following those of a thermometer above ground at an interval of about three or four days. On an average, twenty-four hours are required for the sun's heat to penetrate to a depth of 1 foot, the actual time varying somewhat with different soils.

The soils most favourable to a high diarrhœa mortality are those of sand, gravel, or marl, in which the constituent particles are small but freely permeable by air and water, and which contain organic matters of animal origin from "made ground," from manured surfaces, or from soakage of excretal refuse from privies, cesspools, and sewers. The soil must be moist, but the moisture must not be sufficient to preclude the free admission of air between the interstices; *e.g.*, soils in which the subsoil water stands sufficiently near the surface to maintain by capillary attraction the dampness brought about by previously greater nearness of the water to the surface, or marly soils containing clay sufficient to imprison enough of the water saturating it at some time previously. The moisture of the soil may arise from surface water sinking into the earth around houses, as well as from the subsoil water from below.

Other factors conducive to a high diarrhœa mortality are crowding of houses on space, so that they have deficient light and external ventilation, the building of houses back to back, domestic overcrowding, darkness and dirtiness of premises, and the keeping of milk and other foods in underground cellars exposed to telluric emanations, or in pantries liable to the entry of drain or sewer air.

As previously stated, the disease is mainly one of early childhood (0-5 years), over 80 per cent. of the mortality occurring under two years of age; but its incidence is by far the greatest on hand-fed infants, hence female factory labour, by depriving infants of their natural food, is a contributing cause. The attacks are usually extremely sudden in their onset; and that diarrhœa is merely one symptom or feature of the illness is shown by the fact that many of the organs of those who have succumbed

are found to be highly degenerated, more especially the kidneys, the liver (fatty degeneration), and the spleen. The lungs, too, are often the seat of pneumonic inflammation. Dr. Klein attributes the disease to the *Bacillus sporogenes enteritidis*.

The following provisional explanation of the occurrence of epidemic diarrhœa is offered by Dr. Ballard:

"That the essential cause of diarrhœa resides ordinarily in the superficial layers of the earth, where it is intimately associated with the life processes of some micro-organism, not yet detected, captured, or isolated.

"That the vital manifestations of such organism are dependent, among other things, perhaps principally upon conditions of season, and on the presence of dead organic matter, which is its pabulum.

"That, on occasion, such micro-organism is capable of getting abroad from its primary habitat, the earth, and, having become air-borne, obtains opportunity for fastening on non-living organic material, and of using such organic material both as nidus and as pabulum in undergoing various phases in its life-history.

"That in food, inside of as well as outside of the human body, such micro-organism finds, especially at certain seasons, nidus and pabulum convenient for its development, multiplication, or evolution.

"That from food, as also from the contained organic matter of particular soils, such micro-organisms can manufacture, by the chemical changes wrought therein through certain of their life processes, a substance which is a *virulent chemical poison*.

"That this chemical substance is, in the human body, the material cause of epidemic diarrhœa."

Dr. Newsholme's researches point to the following circumstances as determining the incidence of diarrhœa:

(1) Towns with water-carriage sewerage have, as a rule, less diarrhœa than those practising other methods of removal. (2) Towns with the most perfect scavenging arrangements have least. (3) Towns having the lowest diarrhœal mortalities are situated on impervious soils, though the converse scarcely holds good; and steep gradients favour a low diarrhœa rate. (4) Given two towns, alike in sanitary and social circumstances, the rate is proportionate to the height of the temperature and the deficiency of rainfall, more particularly during the third quarter. (5) There is a general inverse relationship between rainfall and diarrhœa, and a direct relationship between temperature and diarrhœa. (6) The soil is a great factor in the causation of diarrhœa, but its influence may be largely discounted by impervious paving in streets and yards, and impervious flooring to houses. (7) The incidence of diarrhœa follows more closely the want of rainfall than the mean temperature of the air; and the efficient washing of streets, swilling of yards, and flushing of sewers reduces it. (8) The disease increases largely in prevalence when the 4-foot earth thermometer reaches 56° F., or when the mean weekly temperature of the air rises to about 63° F.

Preventive measures are mainly designed to prevent the pollution of the air and soil in and around houses, to encourage the practice of habits of domestic cleanliness, and the protection of food from all sources of pollution. More especially during the summer months should all milk be boiled shortly before use, and the feeding-bottles for infants should be kept scrupulously clean. All food should be stored in a light airy place and carefully protected from dust; fruit and vegetables should be thoroughly cleaned before consumption; and no tainted food or unripe or overripe fruit should be eaten.

During the decennium 1881-90, the death-rate in England and Wales from diarrhœal diseases was 0·67 per 1,000 living at all ages. Under five years of age, the death-rate was 4·3 per 1,000; and although this high rate is largely contributed to by the improper nourishment and feeding of infants, there can be no doubt that insanitary conditions, of the kinds named above, play a large part in its production. For the ten years, 1871-80, the death-rate in England and Wales from diarrhœal diseases was 0·93 per 1,000 living at all ages.

Tuberculosis.

Tuberculosis is a disease to which all warm-blooded animals appear to be susceptible. The degree of susceptibility varies considerably amongst different races of men, and amongst individuals of the same race. The offspring of phthisical parents are no doubt born with a certain degree of susceptibility of tissue to attack by tubercle. It is for this reason that the disease was believed to be hereditarily transmissible. If, however, the disease is congenital at all—*i.e.*, directly transmissible from parent to child—it can only be so to a very trifling extent. Bang has shown that when the calves of tuberculous cows are separated from the mothers and placed under hygienic conditions, they do not develop tubercle in any greater degree than the calves from healthy parents. He found that tubercular lesions at birth are extremely rare, and when present are due to infection through the placental circulation. Investigations by Delépine, Boltz, etc., show no observed tuberculosis in the first, second, and third weeks of life; and Koch has found that guinea-pigs remain healthy if reared apart from tuberculous parents.

The Registrar-General includes in the term tuber-

culosis, "phthisis," "tabes mesenterica," "tubercular meningitis," and "other forms of tubercular disease and scrofula."

If the vital statistics of tuberculosis in this country during the last half-century are studied, it is found that—

1. There has been a marked and progressive reduction in the death-rate, and that the reduction is most marked during the 10-35 years age-period.

2. There has been a still greater reduction in the death-rate from pulmonary tuberculosis or phthisis, this reduction having been most marked at the several age-periods ranging from infancy up to thirty-five years.

3. There has been a large increase in the death-rate from tabes mesenterica under one year of age, and the reduced mortality for the 0-5 years age-period has been insignificant. This fact seems to point to the disease being maintained among infants through the agency of infected milk, but some of the increase may be due to a more extended use of the term "tabes mesenterica" in the registration of infantile deaths.

The principal predisposing causes of the disease are: Foul air; dusty occupations; dampness of site and of premises; dirtiness and darkness of dwellings; poverty, with its attendant insufficiency of food and liability to exposure; and alcoholism. Tissue injuries and malformations of the chest are less prominent predisposing causes. The part which "overcrowding" (foul air) plays in promoting the prevalence of phthisis is well shown by Dr. Tatham's investigations at Salford. Thus, in districts where *all* the houses were built on the vicious system known as "back-to-back," the phthisis death-rate was 5·2 per 1,000 living; where 56 per cent. of the houses were so built, the rate was 3·6; where 23 per cent. only were so constructed, it was further reduced to 3·3; and,

lastly, where there were *no* "back-to-back" houses—that is to say, where all the houses were provided with some means of light and air both in front and to the rear—the rate was only 2·8 per 1,000. These results are all the more remarkable because, with the exception of the means for through ventilation, the back-to-back houses on the whole were, in Dr. Tatham's opinion, in better sanitary condition than the other houses.

Dr. Buchanan, in his well-known report (Ninth Report of the Medical Officer of the Privy Council) has shown that the effect of drying the soil, in the case of towns where the level of the subsoil water was previously high, was to greatly diminish (by $\frac{1}{3}$ to $\frac{1}{2}$) the death-rate from phthisis. The connection between phthisis and moisture in the soil, which had been previously pointed out by Dr. Bowditch of Massachusetts, was thus confirmed by Dr. Buchanan; and this discovery is one of the most interesting and most important, in its bearing on the public health, in the whole range of sanitary science.

The *materies morbi*, the bacillus of tubercle, is contained in the expectoration of phthisical persons. When this is allowed to dry and mingle with the dust of rooms and streets, the bacillus may be inhaled by others, and so infect them. Dujardin Beaumetz gives a striking history of eleven out of twenty-three clerks in an office being attacked during the course of twelve years, as the result of the introduction of the disease by the first sufferer. The floor of the office was rough, no spittoons were provided, and the air was dust-laden from recent sweeping when the men arrived in the morning. The floor was planed and beeswaxed, expectoration was prohibited except into the spittoons which were supplied, and the cleansing done overnight, as far as possible, with damp cloths, with the result that no further cases occurred.

In other forms of tuberculosis the infection may be swallowed, or directly inoculated from discharges. As has been already stated, milch-cows are particularly susceptible to tuberculosis, and in advanced cases of the disease their milk may contain the bacillus, human beings being thereby infected. The flesh of bovines, when eaten in a partially cooked condition, may also be capable of conveying the disease.

Under the term "pseudo-tuberculosis" a whole series of lesions, similar to those induced by the *Bacillus tuberculosis*, is included. This condition, which is rare in man, is mostly caused by some aspergillus or streptothrix, and more rarely by nematodes; but in either case gray nodules and caseating tubercles present appearances very liable to be mistaken for tuberculosis both in quadrupeds and birds. The disease known as actinomycosis is often mistaken for tuberculosis, and *vice versâ*.

The preventive measures which may be taken to reduce tuberculosis may be summarized as—

1. The compulsory notification of phthisis.

2. The removal of those conditions of domicile and of occupation which are known to promote the incidence of the disease, including the regulation of certain dusty trades.

3. The diffusion of knowledge (by medical men, leaflets, etc.) regarding the nature and modes of spread of the disease, and the precautions which should be taken in order to prevent its extension.

4. The testing of sputum and other suspected discharges, and of milk, meat, etc., supposed to be tuberculous—reports to be furnished free of charge.

5. Local authorities to undertake, without charge, the disinfection of houses recently occupied by phthisical persons.

6. The establishment of sanatoria and isolation accommodation for the cure of phthisical patients, and the isolation of those who are a distinct source of danger to fellow-lodgers or workers.

7. The enforcement of measures against spitting in public conveyances and in places of public resort.

8. The efficient sanitary supervision of dairy-farms, dairies, and milkshops. The periodical veterinary inspection and testing (by tuberculin) of milch-cows, and the slaughter of tuberculous animals. The prohibition of the sale of milk of cows affected with tuberculosis.

9. The proper inspection of meat in public abattoirs, and the adoption of due precautions for the control of imported meat and milk.

There is at present a considerable divergence of opinion respecting the desirability of making the disease compulsorily notifiable. If "tuberculosis" were made notifiable, the term would cover an enlarged cervical gland, white-swelling of joints, and hydrocephalus—conditions which are in no sense a source of danger to others—so that notification would have to be restricted to phthisis or "tuberculosis with discharges."

It will be convenient to group the main arguments advanced for and against the compulsory notification of phthisis.

Those who favour such notification urge that making the disease notifiable would educate the public as to the seriousness of the risks of its spread; that the measure is essential in order to obtain knowledge of the exact distribution of the disease, and this knowledge is a necessary preliminary to the discovery and removal of all of those conditions which promote the incidence of the disease; that upon notification the case could be visited, certain precautions (personal to the patient) directed, and dis-

infection carried out; that these necessary measures could be largely left to the medical attendant and the patient; that it would not be necessary to deprive the patient of employment, except in advanced cases, and where this is found to be unavoidable it is better that one should suffer than the many; and, furthermore, success is claimed for the system of compulsory notification as practised in parts of New York.

Those opposed to such notification hold that the long duration of the disease (averaging three years in cases ending fatally, and so unlike the acute specific diseases of short duration now notified), would cause much difficulty in bringing it under any valuable measure of municipal control; that the fact of making it notifiable and classing it with the other infectious diseases would cause the public to exaggerate the risks of infection, and lead to social ostracism and to difficulties in the way of the sufferers gaining a livelihood; that the consequent desire to keep the existence of the disease a secret, together with the fact that the condition is diagnosed with difficulty, and often only at the later stages, would seriously impair the value of notification and of the preventive measures which should follow upon it; that the health officer can do practically nothing to insure the adoption of efficient precautions—which must be taken by the sufferer; that a serious effort to insure the adoption of the necessary precautions would necessitate frequent inspections, and much undesirable friction as the result; that the notification records for the entire country would be very inexact, for phthisical patients are pre-eminently migratory, either from choice or from necessity (from loss of work), and many cases would be repeatedly notified in different districts; that there has been a great reduction in the mortality from the disease without notification;

and that our knowledge of the causes affecting the prevalence of the disease is sufficient to enable an opinion to be formed as to where it prevails in any given district, without notification.

Many, while favourable to the compulsory notification of the disease, are of opinion that as a preliminary measure some hospital isolation provision for the most advanced and dangerous cases should be provided, and that some provision should also be made for hospital treatment of the early stages of the disease in necessitous patients, and for those who would suffer loss of employment or support by reason of their isolation. If such municipal sanatoria are established, a considerable number of beds will be necessary, if a cure is always aimed at, because of the prolonged residence of each patient in the hospital; but great good would accrue if only temporary residence were afforded, as a result of the education and training which the patient would receive. In Germany sanatoria for the poor have been established by municipalities, by benevolent associations, and by insurance companies; and France, Norway, and Russia have State sanatoria for the poor. The economic results of the institution of the sanatorium system by insurance companies in Germany have fully justified the expense involved.

In the absence of State insurance of the working classes in this country, the duty of founding sanatoria for the poor must fall on the municipalities and the Poor Law authorities.

Epidemic Influenza.

Influenza in its epidemic form is an infectious disease, and should be classed with specific fevers. Nothing very definite is known of the etiology of influenza, and so far

the evidence under this head is mostly of a negative character. For instance, it does not appear to show a preference for any particular localities, nor to follow always the same channels of communication; and it has prevailed independently of season, climate, and weather. The disease does not seem to associate itself especially with insanitary surroundings, and the incidence upon the poor is generally lighter than upon the better class of the population.

Although now generally regarded as infectious, and propagated mainly by human intercourse, it was at first supposed that influenza was spread chiefly by an air-borne miasm, and not by personal infection or fomites in the ordinary way. The facts relied upon were the rapidity of spread of the epidemic, and the supposed simultaneity of outbreak upon large numbers of people. But it is now recognised that the rapidity of spread is not greater than human intercourse with modern facilities of travel, and that scattered cases usually precede the general onset of the epidemic upon a community. The epidemic, moreover, has often been observed to travel in directions opposed to the prevailing winds, and to be independent of any particular kind of weather. There can be no doubt that those engaged in out-door occupations are often first attacked, but such people—especially postmen and policemen—may be exposed to contagion before the rest of the population. Equine influenza occasionally precedes the human disease in its epidemic form, but this is by no means invariable. It is even doubtful if the maladies as seen in animals and men are really identical, *i.e.*, dependent upon a common cause.

The chief arguments in favour of personal communicability are: (1) The very frequent occurrence of multiple

cases in succession in the same household. (2) In many instances the first case in a household or neighbourhood can be traced to exposure to infection from a previous case, or to a visit to an infected locality. (3) The special incidence of the disease upon persons liable to come into contact with infection—*e.g.*, medical men and nurses. (4) Persons living under circumstances in which the possibility of infection can be excluded (prisoners in gaols, sailors at sea, lighthouse-keepers) have escaped influenza altogether. (5) That, as a general rule, in each country it has appeared first in the capital or ports of entry, and the towns have been infected earlier than country places. (6) That neighbouring communities have in certain instances been affected at considerably different dates.

The sudden, almost simultaneous attacks of large numbers of people, following upon the appearance of a few scattered cases, is accounted for by the very general susceptibility to the disease, and its short incubation period (forty-eight hours or less).

There is considerable evidence in favour of the bacillus of Pfeiffer, Kitasato, and Canon being the specific organism of influenza, it being found in almost pure cultures in the bronchial secretions of influenza cases, and not in other allied diseases.

As regards age and sex incidence, those in the middle periods of life (twenty to sixty years) are most attacked; people over sixty come next, and children least. Males at all ages are more liable to attack, and with greater severity, than females. All depressing influences, chills, and fatigue are said to favour the development of the disease; but vigorous health is no preventative, and no guarantee that the malady will assume a mild type. The incubation period is usually between two and four days, but may be only one day, or may extend to five. The

average duration of an attack is ten days. The duration of infectiveness is not certainly known, but may continue into the stage of convalescence. One attack is not protective, and relapses are frequent.

Three types of the disease are known, in which the respiratory organs, the alimentary system, and the nervous system are respectively most affected. In different epidemics one or other of these types may prevail more extensively than the others.

During an epidemic the direct mortality from influenza as a primary cause of death may not be more than 0·5 per 1,000; but if to this death-rate we add the mortality indirectly due to influenza, and in addition the excess of deaths from pneumonia, bronchitis, and heart diseases over the average of non-influenza years, the death-rate from this disease and its after-consequences is not far short of 2 per 1,000, or nearly equal to the total zymotic death-rate now recorded in many large towns. The epidemic in London of 1891 was considerably more fatal than that of 1890, and the epidemic of 1892 far exceeded in severity that of its predecessors. The 1894 epidemic was of less severity, whilst the last marked epidemic at the commencement of the year 1895 was but little less severe than that of 1892. During the past five years epidemics have prevailed in various parts of the country, but the mortality resulting has been much less serious than in the first five years of the appearance of the disease.

About 50 per cent. of the deaths from influenza are of persons aged sixty years and upwards.

As regards prevention, theoretically, notification of cases, isolation of the sick, and disinfection of premises, should be, as for other infectious diseases, the proper means of checking or stamping out an epidemic.

But such measures are really impracticable, owing (1) to the difficulty of making an exact diagnosis in the early stages of the first cases of an epidemic, or of mild cases at any time; (2) to the wide and rapid diffusion of the infection, and to the fact that the wage-earning periods of life are most affected, the movements of adults being far more difficult to control than those of children; and (3) to the impossibility under the circumstances of treating influenza as a dangerous infectious disease, the sufferers from which render themselves liable to a penalty, if found exposing themselves in public places. An effort, however, should always be made to promptly isolate the first case occurring in a house or institution; to carefully disinfect the sputum; to avoid exposure to cold and fatigue; to clothe the body warmly and to avoid indulgence in excess of alcohol; and to avoid places to which large numbers of the public resort.

Contagious Ophthalmia.

There are two kinds of contagious eye disease: the gray granulations (trachoma) and purulent conjunctivitis; but the former also appears to predispose the sufferer to take the latter. These diseases are not uncommon in industrial schools and barracks, which are badly ventilated, and where the inmates are not supplied with separate basins and towels for ablution. They are chiefly transmitted from the sick to the healthy by inoculation of the eyes with the secretions and discharges left on linen and towels; but it is also probable that the contagion is carried through the air in dried epithelial or pus cells.

The ophthalmia caused by gonorrhœal infection of the eyes, and the ophthalmia neonatorum, inoculated from purulent vaginal discharge, are especially virulent and destructive forms of eye disease. In all forms of puru-

lent ophthalmia a pyogenic micro-organism is probably the active cause of the disease.

Plague.

An epidemic disease having the characters of bubonic plague is referred to by many old writers, as far back as 2,000 years ago, as prevalent in Egypt, Libya, and other parts of North Africa. The most appalling European visitation was that in the fourteenth century, known as the "Black Death," which was supposed to have had its origin in China in 1334; this outbreak lasted many years. The Great Plague of London made its appearance in 1664, lasted about one year, and destroyed at least 63,000 persons.

China and the western parts of India appear to have always suffered most; and it is generally recorded that plague in its manifestations attacked districts for a number of successive years, with short intervening periods of apparent freedom.

The disease is of microbic origin, and is due to the bacillus isolated at Hong Kong in 1894 by Kitasato and Yersin. This bacillus is found in the blood and in the discharges from the sufferers. The infection can be contracted by inoculation, inhalation, or by swallowing; and human sufferers are not the sole carriers of contagion. Rats, mice, cats, monkeys, pigs, and probably sheep, goats, dogs, and other animals may also suffer from the disease, which in China and the Himalayas is called "the rats' disease." If dead or dying rats are found, the natives of these parts often flee from their houses, which in India are generally honeycombed by rat-runs. There is evidence to show that rats may be affected before human beings; and it is certain that the continuance and spread of the disease is favoured by the presence of these highly

susceptible animals, many outbreaks having been attributed to infected rats, conveyed from an infected to a non-infected port, in grain-carrying ships. It is probable that the infection is conveyed from rats to human beings by means of fleas. On the death of a plague-stricken rat, the fleas—already engorged with bacilli—leave the body, and find their way into houses, where they attack man, inoculating him through the "bites."

Direct contagion from the sick to the healthy appears to be a minor cause of spread, Europeans having suffered but very little while in attendance on Indian patients. Like typhus fever, plague appears to be associated with conditions of poverty, filth, and overcrowding, and more especially with soil polluted by organic matter. It has not yet been demonstrated that drinking water has acted as a disseminator of the virus, although experiment shows that the plague organism can live for a long time in water. Fomites retain and spread the infection. Although rare in equatorial regions, it occurs in hot and cold weather, wet and dry seasons, on dry and damp sites, and at all altitudes.

There are three distinct types of the disease: the bubonic, the pneumonic, and the septicæmic; but the first-named is so much more common than the others that the disease is very generally known as "bubonic plague."

The incubation period of bubonic plague varies from two to seven days; and generally within twenty-four hours, or less, from the onset of symptoms the buboes appear in the groin, the armpit, the region of the neck, or more rarely elsewhere. Death frequently takes place within forty-eight hours from the onset of symptoms, a fatal result being rare after the eighth day. The disease varies so much in its clinical aspects and severity as to

justify a rough classification of cases into severe and mild, or pestes major and pestes minor.

The preventive measures against the disease include: The discovery of cases by house-to-house inspection, where necessary, and the early bacteriological diagnosis of the mild and non-bubonic types of the disease which have been observed to precede an outbreak. Prompt and efficient isolation and disinfection should follow upon the discovery of the cases; and those living in the same house with a plague patient, the so-called "contacts," should be removed from their homes to a quarantine house, to be kept under observation for ten days. Both prophylactic and curative inoculations with Haffkine's fluid and Yersin's plague serum respectively, are further measures of undoubted value, which should be practised when possible. The total destruction of the rats in an infected area is eminently desirable to check the spread of the disease, but the due execution of this precaution has hitherto presented insuperable practical difficulties. The numbers of rats, however, may be materially reduced by trapping or poisoning, or by asphyxiating them in their hiding-places with sulphurous acid gas, and their dead bodies should be immediately burned. Efforts, not yet successful, have been made to communicate an epizoötic disease to rats and mice, which, while not communicable to man, would spread among the rodents and cause their destruction.

The evacuation of infected houses, and even of infected districts, has been attended with good results in India, the people being housed temporarily some distance away, while the sufferers are isolated, and the infected clothes and premises disinfected. To guard a district against the importation of the disease, all persons coming from infected localities must be subjected to at least seven

days' surveillance; and provision should be made for the medical inspection of all incoming persons at the railway centres, and at other means of approach to the district. Anyone found to be suffering from the disease must submit to hospital isolation, and suspects must be detained temporarily in quarantine camps. As the disease is essentially a filth disease, every effort should be made, by improved scavenging and the removal of insanitary conditions, to stamp out the possible foci of infection.

Haffkine's prophylactic against plague consists of a fluid prepared by sowing plague bacilli in a neutral mutton broth on which floats a small quantity of cocoanut-oil. The bacilli attach themselves to the oil globules, and form stalactitic growths projecting into the broth. When the growth is at its height, the culture is heated to 70° C. and carbolized, and a limpid fluid separates out on standing. Of this solution 2·5 c.c. is inoculated, and the inoculation is repeated in ten to fourteen days. A good deal of reaction results, the temperature rising to 102° F., sometimes to 104° F., with a feeling of general malaise and pain at the seat of inoculation. The India Plague Commission has recently reported that inoculation of Haffkine's fluid sensibly diminishes the incidence of plague attacks, and also the fatality of attack among the inoculated population.

Yersin's serum is prepared in the same way as diphtheria antitoxin, by inoculation of horses with living cultures of plague bacilli. The immunity given by inoculation of Yersin's serum is of much shorter duration than that due to Haffkine's prophylactic. Fifteen days is about the limit of the immune period due to the serum, whereas Haffkine's fluid may be protective for several months.

Malaria.

It has now been demonstrated (Ross, Koch, Celli) that man is the temporary host, and the mosquito the definite host, of all known malarial parasites. These parasites pass their asexual life, and prepare their sexual forms, in the human blood, while they complete the sexual cycle of life (that by which the species of the parasites external to man is assured) in the middle intestine of the mosquito. Those mosquitoes capable of affording lodgment to the specific parasites, and of infecting man by means of their punctures, appertain to the genus Anopheles. Some species, but not all, of Anopheles can be distinguished from the genus Culex—the common gnat, a harmless insect—by the circumstance that, when the former alights on an object, the long axis of the body is almost vertical to the resting surface, while in Culex it is parallel; the Anopheles, moreover, does not make so loud a humming sound as the Culex.

The soil plays only a secondary, indirect part in the propagation of malaria, by its favouring or otherwise the life and development of the malarigenous mosquitoes. The most favourable soil for malaria is that which permits of the formation and continuance of pools of stagnant water containing algæ or water-weeds, which are the habitat of the eggs, larvæ, and nymphæ of the genus Anopheles.

It is generally admitted that chilling of the body predisposes both to the onset of the primary infection and to relapses. The inhabitants of malarious districts in the tropics acquire a natural immunity, as a rule, after a few years of life in these regions, and some degree of immunity is developed among immigrants after three or four years. Among prophylactic methods should be included the ability to make an accurate diagnosis of the

complaint, and to recognise the plasmodium in blood submitted for examination. After diagnosis the patient should be isolated, if possible, in some place where malarial mosquitoes do not exist, for he is otherwise liable to be bitten by infected mosquitoes, and therefore to become the subject of contemporaneous infection by various different malarial parasites. By reason also of the sexually developed parasites in his own blood, he is a possible source of infection to uninfected mosquitoes, and consequently of danger to man. The main prophylactic measure, however, is directed towards the destruction of the larvæ in the water. For this purpose petroleum and certain aniline dyes appear to be efficient, if rightly used. The petroleum acts mechanically by asphyxiating the larvæ and nymphæ, which float flat on the surface of the water, and it must therefore form a stratum, covering the whole surface of the water. The most suitable time for destroying the larvæ is the winter or the beginning of the spring, when they are fewest in number in the water, and the new generations have not yet made their appearance.

Among the odours which are obnoxious to the perfect mosquito are turpentine, menthol, and garlic; among the fumes, tobacco and simple wood smoke; among the gases, the most practical and efficacious is sulphurous acid.

An effort should be made to protect the body against the bites of all proboscidian insects, especially at night, by means of mosquito-curtains, and by inunction of the skin with oil or liniment containing camphor or eucalyptol. The use of perfumed soaps may afford some protection to the face and hands. Suitable clothing should be worn to protect the body from chills. Since Anopheles larvæ are mostly found in stagnant puddles containing algæ, all such pools and puddles should be filled in, drained, or

otherwise dealt with, so as to permit of no place remaining where the mosquitoes can deposit their eggs.

All the old observations regarding malaria can now be accounted for, and their real significance understood. Thus, it is an old theory that malarial miasmata rise from stagnant water, that malarial outbreaks depend on rainfall, that they can be obliterated by drainage of the soil, and that they are often due to disturbance of the soil, all of these being factors which determine the existence of puddles affording suitable breeding-grounds for Anopheles. Old observers have also noted that malaria is most likely to be contracted about sunset and at night, that the "miasm" did not extend to any great elevation above sea-level, and was not carried by high winds. These facts are all explained by the mosquito theory of infection, for the insects issue forth at sunset, and pursue their search for food through the night, never mounting high in the air, and avoiding windy or stormy nights.

Varicella.

Varicella, or chicken-pox, is often mistaken for mild or modified attacks of small-pox, but the two diseases are quite distinct. It is a mild disease, but rarely fatal when uncomplicated with other disease, and its attacks are chiefly confined to children. The incubation period varies from thirteen to nineteen days, and is commonly about fourteen days. The infection of varicella is very active from the first, and is capable of remaining active for some time in fomites. The patient should be isolated until the last scab has fallen off.

Mumps.

Often in cold and wet weather an epidemic of this disease breaks out, the infection spreading with great

rapidity, but giving rise to little, if any, mortality. Outbreaks are often associated with an epidemic of measles. Nothing is known of the etiology of the disease, and one attack generally confers immunity from others. The disease attacks chiefly the early age-periods of life, and the incubation period varies from fourteen to twenty-five days. The swellings of the parotid and submaxillary glands, which are the most prominent symptoms, generally remain for about a fortnight.

Rheumatic Fever.

There is good reason for believing that this disease is a specific disease, and quite distinct as to its origin from ordinary rheumatism. The facts supporting this view are: (1) There are great irregularities in the incidence of rheumatic fever year by year; excessive, or even epidemic, prevalence tends to manifest itself at irregular intervals of from three to six years. (2) Dr. Newsholme's researches have shown that there is a very definite relationship between deficient rainfall, low ground water, and high soil temperature on the one hand, and the prevalence of rheumatic fever on the other. In Norway the disease is compulsorily notifiable by medical attendants, and exceptional opportunities are thus afforded in that country of studying the epidemiology of the disease. Elsewhere, the evidence collected is generally derived from hospital returns. (3) The type of the pyrexia, and the articular and cardiac disturbances, are best explained on the microbic doctrine. (4) The marked effect of the administration of salicylates has long been claimed as proof in support of the specific nature of the disease.

Leprosy.

Doubt still exists as to whether this disease is ever conveyed by direct or indirect communication between the sick and the healthy. The wives, husbands, or parents of leprous patients, who have elected to be segregated with them on the Island of Molokai—one of the Hawaiian group—do not appear to succumb to the disease in any exceptional proportion as compared with the general population of the islands. Dr. Ashburton Thompson's recent investigation into the subject supports the view that "the vast majority of instances of apparent spread of leprosy by infection are spoilt by having been observed on areas of recognised endemicity, so that the influence of locality cannot be excluded. . . . It appears clear that leprosy is only communicable by the sick, if at all, with great difficulty."

Beri-Beri.

This is a disease characterized by difficulties of movement, often attended with some atrophic paralysis, more particularly of the lower limbs, by disorders of sensation, œdema of the skin, and dropsy of the serous cavities. There are several types of the disease; in one the nervous symptoms predominate, in another the respiratory system suffers most, and in a third (œdematous) type the circulatory organs appear to be most affected. The disease is essentially a chronic one, and it is said that dirt, dampness, and overcrowding predispose to it. Possibly patients with open wounds may infect others, but the disease does not appear to be communicable in any other sense. Some ascribe a food origin to the disease, and it has been shown that the administration of fat is valuable in arresting symptoms. The etiology of the disease, however, must still be regarded as obscure.

Dengue.

This specific febrile disease is peculiar to warm climates, and is characterized by severe muscular and articular pains, and sometimes by a cutaneous eruption. It is specially prevalent in the dry, hot seasons of very warm climates, so that a high temperature is doubtless one factor which determines incidence. One attack is generally protective, and the disease spreads by personal communication.

Epidemic Pneumonic Fever.

That pneumonia may occur in epidemics, or even pandemics, has been recognised for many years. The mortality of several outbreaks in this country has attained the figure of 5 per 1,000 living of the community. So far as has been ascertained, neither meteorological nor insanitary conditions appear to exercise any marked influence on the epidemic prevalence of pneumonia.

Puerperal Fever.

Puerperal fever is generally caused by the introduction of infection into the genital tract from without the body, and usually by the neglect of aseptic precautions, during and immediately after childbirth. The term " puerperal fever " has been defined by the Royal College of Physicians of London as including " septicæmia, pyæmia, septic peritonitis, septic metritis, and other acute septic inflammations in the pelvis, occurring as the direct result of childbirth."

Insanitary conditions, more especially the fouling of air by overcrowding and drainage defects, probably play some part in the origin or propagation of the disease; and there is some evidence that the infection of erysipelas is capable of giving rise to puerperal fever.

Cancer.

The causes determining the prevalence of this disease are still wrapped in some obscurity, but the view that cancer is due to a parasite, which possesses some degree of infectiveness, is gaining ground. Recent research seems to indicate that cancer, like enteric fever, has an endemic prevalence, and that it affects in a higher degree populations living in low-lying river valleys with clay soils than those on high, dry, and non-retentive soils. An endemic area may be close to others on which the disease rarely occurs; and isolated "cancer houses," or groups of such houses, are held by many to exist in certain districts.

The death-rate from cancer varies considerably in different parts of England and Wales, ranging from 440 per 1,000,000 in Durham, 475 in Staffordshire, 477 in Lancashire, and 482 in Derbyshire and Monmouthshire, to 716 per 1,000,000 in Norfolk, 727 in Sussex, 736 in North Wales, 740 in Devonshire, 789 in Cambridgeshire, and 916 in Huntingdonshire.

During the past fifty years there has been an increased mortality from the disease in England and Wales, as the following table serves to show:

DEATHS PER 1,000,000 LIVING AT ALL AGES.

	1851-60.	1861-70.	1871-80.	1881-90.	1891-97.
Males ..	195	242	312	430	571
Females ..	434	519	617	739	882

This increase is probably not altogether a real increase, but is to some extent apparent, and due to better diagnosis and certification of causes of death. "The cancerous affections of males are in much larger proportion internal or inaccessible than are those of females, and

consequently are more difficult of recognition ; so that any improvement in medical diagnosis would add more to the male than to the female figures" (Ogle). It is a significant fact, therefore, that among males aged thirty-five to forty-five the rate of increase has been 89 per cent., while among females at the same age it has not exceeded 37 per cent. Moreover, in Frankfort-on-Main, the deaths are classified into those of inaccessible and accessible regions, and the increase of cancer is confined to the former. The greater number of survivals to the higher ages of late years will also account for a slight increase in the incidence of a disease of a degenerative type, such as cancer. But despite these facts some of the increase appears to be real, and in this increase there is a marked predominance of cancer of the digestive organs.

Cerebro-spinal Fever, or Epidemic Cerebro-spinal Meningitis.

The specific character of this disease is now generally recognised, but probably many cases so diagnosed are really suffering from tubercular meningitis or meningitis due to pneumococcus infection. Cerebro-spinal meningitis is not an infrequent complication of many febrile diseases, but this form is never epidemic or communicable ; nor is it attended by the purpura or herpetic eruptions characteristic of cerebro-spinal fever. The latter is also distinguished by the absence of any associated disease.

The disease is rare in this country, but is more prevalent in the United States and some other countries, and is probably on the increase. An organism having a diplococcus form, and often called the meningo-coccus, is believed to be the specific organism, and the same organism has been found in cases of infantile paralysis.

Animals, especially horses and pigs, are probably also liable to the disease. The diplococcus is said to be constantly present in the nasal discharge of sufferers; and this discharge is sometimes so profuse as to cause the disease to be mistaken for influenza. This discharge is probably the main channel of infection. Overcrowding and bad air appear to predispose to attack. The disease affects children and young people, often in epidemic waves, and the case mortality is generally very high. The diagnosis can be confirmed bacteriologically by a lumbar puncture, which is almost painless, below the end of the spinal cord; and an examination for the diplococcus can be made in the fluid so obtained.

Epizootic Diseases.

Anthrax.

This specific disease affects cattle most frequently, but all animals are capable of being infected. The infection generally enters the body through the alimentary tract, but it may be introduced through the respiratory tract, and also through the skin by inoculation (by the stings of insects, etc.). When the soil becomes infected, as by discharges from animals, the disease may spread rapidly and extensively through herds. Pasteur and others have held, on experimental evidence, that when animals dead of the disease are superficially buried, earth-worms may be instrumental in conveying the specific organism to the surface. The grass may become extensively contaminated by discharges, the specific organism persisting for considerable periods in decomposing animal and vegetable matter. Animals feeding on infected pastures may become inoculated through wounds inflicted on the buccal mucous membrane and the tongue by

silicious grasses. The disease is most prevalent on warm, loose, moist soils, rich in organic matter, especially in swampy, boggy districts, and during the summer months.

Man is generally infected during the process of killing and skinning diseased animals, and possibly by eating the flesh. In this country the sorting and handling of dried skins or hair imported from abroad is most frequently responsible for the disease. Man is infected either by direct inoculation of a wound or abrasion on the face and hands, which gives rise to the malignant pustule, or by inhalation of the dust, containing spores, into the mouth or lungs, when general infection of the system follows, usually proving fatal in the course of a very few days. The symptoms of general infection are usually obscure, and appear to depend upon the organ with which the virus first comes in contact. If the dust is swallowed, the stomach and bowels are chiefly affected; if inhaled, the lungs. Bacilli are found in the serum of the pustule, in the various secretions, and in the blood after death.

The disease may assume the following types, each of which is also met with in man:

1. "Apoplectic": Symptoms of cerebral apoplexy appear; the animal is taken suddenly ill, staggers, and falls, and dies in convulsions in from a few minutes to one hour at most. This is the most usual form in sheep and goats.

2. A condition of excited restlessness is followed by convulsions, stupor, and death, as if from apoplexy. The symptoms last from two to twenty-four hours in this form, which is the most usual in cattle.

3. "Anthrax fever": This is the most common form, lasting from twenty-four hours to seven days. High fever and frequent colic are followed by symptoms similar

to those of the last type, but the grave symptoms are intermittent, and their duration is more prolonged.

4. "Carbuncular disease": Characterized by circumscribed cutaneous swellings, at first hard, hot, and painful, and later becoming cold, painless, and with a tendency to slough, but not to suppurate; œdematous swellings of the skin; similar swellings on the mucous membrane of the mouth, pharynx, larynx, and rectum; irregular fever;* dyspnœa; difficulty in swallowing; tenesmus. This form generally lasts from three to seven days.

The post-mortem diagnosis depends upon: (1) The discovery of the bacillus, and the results of its inoculation into mice; (2) hæmorrhages of variable size, often evident in all the organs and in the subserous, submucous, and subcutaneous tissues, and serous infiltration and congestion of organs generally; (3) swelling of the spleen to from two to five times its normal size: the liver, kidneys, and lymphatic glands are also enlarged, though to a less degree; (4) a tar-like condition of the blood. The bodies are often well nourished; there is an absence of rigor mortis, rapid decomposition sets in, and where there is considerable œdema there may be wide areas of necrosed skin.

In this disease, as in some others, such as chicken cholera, rabies, and swine fever, the virus can be attenu-

* The following are the symptoms of fever in cattle: The temperature (*per rectum*) is generally about 41° to 42° C.; the external temperature of the body is unequally distributed; the hair stands on end and loses gloss; feeding and rumination are suspended; great depression; eyes dull and congested; tongue protruded; often diarrhœa; short panting respirations; frequent small pulse (60 to 120 per minute); nostrils dry or covered with foam; in cows secretion of milk is diminished and the teats are hot; rigors.

In horses the symptoms are similar; the temperature is generally about 39·5° to 41·5° C., and the pulse from 80 to 100 per minute.

ated by cultivating the bacillus at high temperatures (42° C. or 43° C.) in sterilized nutrient media for a varying number of days, or by growing it in medicated gelatine—corrosive sublimate 1 part, gelatine 40,000 parts (Klein). When cultivated at 42° C., the bacilli produce no spores, and the intensity of their virulence decreases day by day. This attenuated virus (or it may be the waste products of its metabolism), when inoculated into susceptible animals, inhibits the growth of the specific microbes when introduced into the body, and is so found to confer immunity for a time from the disease in its virulent form. The same result can be attained when the bacillus from one species of animal is passed through a different species. If the bacillus of sheep or cattle is inoculated into mice, the organisms taken from the mouse are attenuated for sheep or cattle, and confer immunity from subsequent attack.

Quite recently mice have been rendered immune against anthrax virus by injection of an albumose (a proteid body) isolated from cultures of the anthrax bacilli, of whose metabolism it is no doubt a waste product (Hankin). The quantity of anthrax albumose necessary to produce immunity is extremely minute.

Sanitary Precautions.—The sorting of hides should be carried out only by experienced workmen, and by those whose hands and arms are quite free from any abrasion. Any suspected wool or hides should be well moistened before handling; but a safer procedure would be to disinfect all bales by steam under pressure prior to handling.

Hoods should be provided over the sorting benches to catch the dust, which may be extracted by fans and collected in a washer or condenser, the water from which should be well boiled before it is emptied down a drain. If the dust is collected dry, it must be carefully gathered

together and burnt. The dust must not be allowed to reach the external atmosphere, or it may be blown long distances and infect grazing cattle.

The premises must be kept clean; the floor of the sorting-room should be impermeable, and washed down with disinfectant solution daily.

There must be adequate provision of air-space and ventilation, and the windows should be thrown open during the meal-hour.

By the Anthrax Order (1899) of the Board of Agriculture, dung and other litter from the place of outbreak are to be burnt, or disinfected, and buried to the satisfaction of the inspector. Carcases must either be buried in lime, as soon as possible, with the skin on, at a suitable place to which animals will not have access, and at a depth of not less than 6 feet below the surface; or they must be destroyed by exposure to a high temperature, or by chemical agents in a horse-slaughterer's or knacker's yard, or other place approved for the purpose by the Board. A carcase of a diseased or suspected animal shall not be buried or destroyed otherwise than by the local authority, nor be removed from the farm or premises upon which the animal died or was slaughtered, except for the purpose of being buried or destroyed. Before a carcase is removed for burial or destruction, all the natural openings must be plugged with tow or other suitable material saturated with a disinfectant. In no case shall the skin of the carcase be cut, nor shall anything be done to cause the effusion of blood, except by a veterinary inspector and for the purpose of microscopical investigation. Disinfection in cases of anthrax shall be performed by the local authority at their own expense, and shall consist in thorough sprinkling with freshly-burnt lime or other suitable disinfectant, and subsequent washing with

limewash containing in each gallon 4 ounces of chloride of lime, or $\frac{1}{2}$ pint of commercial carbolic acid. The measures applicable to fields are left to the discretion of the local authority or their inspector.

Tuberculosis in the Lower Animals.

The disease is characterized by nodular, cellular, non-vascular foci (tubercles), frequently translucent and hard, about the size of a millet grain, which cannot be shelled out from the surrounding tissue.

The disease is most frequently found in cattle, pigs, and birds, but occasionally in all warm-blooded animals.

The symptoms commence insidiously, and are as follows: A dry, short, jerky cough; increased sensibility of the chest walls; at a later stage, spasmodic paroxysms of cough, especially in the early morning—percussion sounds dull on circumscribed areas; diminished secretion of milk; flatulence; dyspnœa (shown by the extended position of the head and neck); intermittent colic, with alternating diarrhœa and constipation; hæmaturia; enlargements of glands; irregular fever; excessive emaciation; weakness; often peritonitis, and swellings of bones and joints. Animals frequently come on heat and remain so for a long time; cows mount their fellows, but are rarely fecundated by bulls; and pregnant cows frequently abort. Brain excitement, convulsions, paralysis, staggers, and sudden collapse, often supervene during the last stages. Tuberculosis of the udder is characterized by a diffuse, painless, and comparatively firm swelling, usually of one-quarter of the udder (one of the posterior quarters as a rule); the milk at first is normal, then becomes thin and watery, with flakes, and sometimes, though not always, the specific bacilli are present. The pudic glands are also much enlarged.

The post-mortem diagnosis is chiefly made from the lungs and serous membranes, which are found to be studded with the tubercle nodules. In the lungs the nodules frequently form grape-like clusters which project from the pleural surfaces. The lymphatic glands of the body generally are often enlarged and affected with tubercles.

According to the experience in the public abattoirs of Germany, the different organs are affected in the following order of frequency: Lungs 75 per cent. of all the cases, visceral pleura 55 per cent., peritoneum 48 per cent., costal pleura 47 per cent., bronchial and mediastinal glands 29 per cent., liver 28 per cent., spleen 19 per cent.; no other part of the body is affected in more than 10 per cent. of the cases, and the udder is affected in only 1 per cent.

In pigs the starting-point of the infection is generally in the intestines, as the infection is almost invariably swallowed; in cats it is chiefly in the lungs. The disease is not uncommon in goats, and therefore the popular belief that goat's milk is safe is not warranted. In birds the leading symptoms are: Emaciation, pallor of the mucous membrane of the eyes and mouth, loss of appetite, vomiting, diarrhœa, swellings of joints, tumours, and sometimes ulcers.

In applying the tuberculin test, the animal is first allowed to become cool and quiet; then the temperature is taken *per rectum*, the thermometer being allowed to remain in for five minutes. The normal temperature of bovine animals ranges from 100·5° to 102·5° F. It is convenient to inject the tuberculin into the neck or shoulder, late in the evening, so that the observation of the reaction temperature may be made early next day. The animal must not be regarded as certainly tuberculous unless the morning

temperature shows a rise of at least 2·5° F. above that of overnight. Animals suffering from advanced tuberculosis often fail to show a marked temperature reaction, or if they are already feverish (*i.e.*, temperature above 102·5° F.), the reaction may not be noticeable. The test must not be repeated until at least a month has expired, as the animal will often not react again in a less period. This fact, it has been suggested, opens the door to fraud, as a dishonest salesman could inject his animals a few days prior to sale, and then sell them as tuberculosis-free. Those animals which react should be isolated, and fattened for food if the disease is not advanced.

Actinomycosis.

This disease affects cattle, pigs, horses, sheep, and man. The symptoms are of long duration, and include: Aversion to food and mastication; swollen tongue; copious salivation; difficulty of swallowing, and dyspnœa, from growths in the pharynx and larynx; swelling of the parotid region, which is covered with tumours of varying size; later, the affection of the cervical vertebræ causes paralysis, and symptoms resembling phthisis result from the implication of the lungs.

To diagnose this disease from tuberculosis, parotitis, cellulitis, etc., the nodules and abscesses should be incised, and a search made for the ray fungus.

The post-mortem diagnosis is established by the discovery of tubercle-like nodules and large lobulated tumours, usually in the upper or lower maxillary bones, sometimes very soft, at others hard. These consist of connective-tissue stroma with numerous interspersed nodules, varying in size from a millet-seed to a pea. These nodules contain the sulphur yellow actinomycosis

granules, about the size of a grain of sand; they may develop into cold abscesses, which contain the small yellow tufts of the fungus. On the sides and under surface of the mucous membrane of the swollen tongue are to be seen rounded, slightly raised, brown spots, through which shine very minute yellow nodules. In the pharynx there are generally soft, fungoid, pedunculated growths with smooth surfaces, and these may form in the œsophagus, larynx, and trachea. Elastic, firm nodules, generally from a hazel-nut to a man's fist, or larger, in size, may be seen in the skin and subcutaneous tissue, chiefly of the head and neck. The lymphatic glands in the neighbourhood of the neck are generally also affected. In the lungs, disseminated, firm, whity-yellow nodules are seen, varying in size from a millet-seed to a pea, which become calcareous in the centre; or there may be large purulent foci. It is not certain if the disease can be communicated to man by contagion or infection, or by eating the infected flesh.

In man the symptoms are: Abscesses, chiefly in the bones of the face and in the tongue. The lungs, liver, kidneys, peritoneum, intestines, and brain may become infected by metastasis. Probably, as in animals, it is transmitted exclusively by portions of plants, which are studded with the fungi.

Rabies.

In this disease the virus is contained in the saliva of rabid animals, such as dogs, horses, bovines, cats, pigs, sheep, goats, and even birds. The disease is spread by inoculation into the skin through the bite of a rabid animal.

The incubation period in dogs is from three to six weeks on an average, with a minimum of a few days, and a maximum of several months. The symptoms of

canine rabies assume two forms—*i.e.*, the "furious madness," which is the more frequent, and the "dumb madness." The symptoms in the furious form follow each other in three stages: (1) The melancholy, (2) the irritative, and (3) the paralytic. *Stage* 1 generally lasts from twelve to forty-eight hours, and is marked by capricious appetite, the animal being sullen, nervous, excited, irritable, and distrustful; it bites at everything, and often swallows foreign bodies. There is sometimes abnormal itching at the site of the bite. *Stage* 2 lasts three or four days, and is characterized by attacks of fury (which may continue for some hours) and convulsions, with remissions. The animal is very irritable, and often tries to run away; it shows an excessive morbid desire to snap, and later to bite, often with such force as to break its teeth. The animal does not try to bite human beings unless approached. Paralysis of the vocal cords often causes a change in voice. Hallucinations are more prominent than mania. In *Stage* 3 the animal is much emaciated, the hair stands on end and is rough, the eyes are sunken and glassy, and the power of swallowing is lost owing to paralysis of the muscles of deglutition; paralysis of the lower jaw then supervenes, and the jaw drops down, the tongue hanging out; the hind-quarters next become paralyzed. The whole stage is attended by paroxysms of excitement, which grow less and less frequent, until the animal dies between the fifth and tenth day.

Dumb madness differs mainly in the absence, or very short duration, of stage 2.

In man there is premonitory pain in the cicatrized wound from the bite, general malaise, swelling of the neighbouring lymphatic glands, and aversion to fluids. In the second stage reflex spasms, delirium, and mania

supervene, the spasms affecting chiefly the throat when attempts are made at swallowing, and being excited even by the sight of water or the thought of drinking; there is also much anxiety, uneasiness, and thirst, and the patient slavers, because of the inability to swallow the saliva. The third stage is characterized by paralysis and spasms, and death supervenes in from two to four days. But few recoveries are recorded.

Whilst in man the usual period of incubation after the infliction of a bite by a rabid dog is somewhere about six weeks, it may be as short as six days or as long as two years (Horsley). The rabic virus is chiefly contained in the nervous centres, and it is presumed that the disease only shows itself when these centres are attacked by the virus. This view explains the unequal length of the incubation period in different cases, the incubation period being governed by the time taken by the virus to travel from the point of inoculation up to the central nervous system, and for its development therein. If the virus travels up the nerves the incubation is long, but if conveyed in the blood-stream the incubation may be very short.

Horsley gives the death-rate among persons bitten by indubitably rabid dogs as on the average about 15 per cent.; that is to say, about 85 per cent. of the persons bitten are insusceptible, or, at least, escape the action of the virus, for rabies once developed is almost invariably fatal.

M. Pasteur has elaborated a system of treatment by protective inoculations, which promises to render hydrophobia, with its terrible sufferings, a thing of the past. Shortly, it may be described as follows: The spinal cord of a rabid rabbit, which, like all parts of the central nervous system, contains the virus, is submitted to a

drying process at a temperature of 25° C. for a certain number of days (three to fourteen). By this means the virulence of the virus (microbe) is destroyed, but waste products of its metabolism are obtained, which inhibit the growth of fresh rabies virus. The injection of this protective substance into the body of a person bitten by a rabid animal prevents the development of the rabies poison. That this is indeed the truth is evident from the fact that persons who have been bitten by indubitably rabid animals, and have submitted themselves to the Pasteur treatment within a few days of the infliction of the bite, have almost invariably escaped. The death-rate, instead of 15 per cent. in the unprotected, is only 1·36 per cent. in the protected. For ordinary bites the inoculations start with the fourteen-days-dried cord, and end with that of three days. For more dangerous wounds the number of inoculations is greater, and the use of the recent cords is more rapidly brought into operation. "This is the 'intensive' treatment, which is used in severe cases—bites on naked parts and wolf bites. Nearly all the individuals treated by M. Pasteur, who have succumbed to the disease, developed it during the fortnight following the commencement of the inoculation, owing to the fact that in their case the virus probably passed in the blood-stream to the nervous centres very soon after the infliction of the bite."

In this country rabies is spread by infected dogs; where muzzling regulations and the slaughter of stray dogs have been enforced, the disease is rapidly exterminated.

The diagnosis of the earlier symptoms largely depends upon whether proof is forthcoming of the animal or man having been bitten by a rabid animal. The post-mortem changes in canine rabies are neither constant nor specific;

but the following diagnostic appearances may be mentioned—emaciation, dark blood, hyperæmia of mucous membranes and of many of the internal organs, the frequent presence of foreign bodies in the pharynx and œsophagus or the stomach, which often contains such articles as straw, hair, feathers, string, wood, or pebbles, but very little or no food. Frequently small hæmorrhages are seen on the surface of the gastric and buccal mucous membrane, and the intestines are generally found to be empty.

Foot and Mouth Disease.

Foot and mouth disease is peculiar to ungulates, and therefore occurs chiefly in cattle, sheep, pigs, and goats; but all wild ruminants are liable to it. The disease is rarely fatal.

The symptoms in cattle are: Vesicles and ulcers on the oral mucous membrane, and on the skin of the coronet and of the interdigital space (sheep, goats, and pigs are usually affected only on the feet). The small yellowish-white vesicles on the gums, tongue, buccal mucous membrane, and lips gradually increase in size, until they become as large as a five-shilling piece, when the vesicles burst, leaving ulcers. There is much salivation, and rapid and great emaciation. The milk is colostrum-like in appearance and taste; and in milch-cows the exanthem often spreads, by the act of milking, to the udders and teats.

In the malignant type, symptoms supervene resembling apoplexy, and the animal dies suddenly from paralysis of the heart, due to the development of toxins. There is often violent inflammation of the udder, with sero-sanguineous discharge; sometimes ulcers form on the pharyngeal mucous membrane, and there is dyspnœa

and nasal and bronchial catarrh. Sometimes the vesicles form on the skin at the base of the horns, also on the vulva and vagina, and on the general surface of the skin.

As regards the feet, there is first a painful swelling of the coronet, especially between the toes and towards the plantar cushions; then lameness results. Erysipelatous inflammation sometimes supervenes, and later on ulcers and abscesses; as a result, the hoofs may be shed. The general constitutional symptoms are those of pyæmia.

The disease is transmitted to man through milk, butter, and cheese, or is inoculated through wounds in the hands and arms. The symptoms are: Fever; disturbance of digestion; vesicles on the face (lips and ears), the fingers, the arms, the female breasts, and the mucous membrane of the mouth, pharynx, and conjunctiva; abdominal pains; and vomiting. Occasionally death supervenes in young persons. The disease is not conveyed by eating flesh.

Glanders.

Glanders and farcy are now recognised as different manifestations of the same disease. It is essentially an equine disease affecting horses, donkeys, and mules; but it may be transmitted from horses to many other animals, including man, by direct inoculation. In some years the disease causes a considerable mortality in this country among horses.

The symptoms may be those of either acute or chronic glanders. Acute glanders is a very rapidly progressive septic infective disease, accompanied by gangrene of the respiratory mucous membrane and by metastatic formations in the skin, lungs, and other organs. The prominent symptoms are: High temperature; rigors; muco-purulent nasal discharge, which later becomes sanguineous, the

visible mucous membrane being covered with nodules and ulcers, which are frequently confluent and covered with diphtheritic sloughing masses; dyspnœa; and roaring inspirations. There are also œdematous swellings of the skin, nodules and ulcers in the skin, cordlike inflammation of the lymphatics (especially in the neighbourhood of the head), swelling and suppuration of the lymphatic glands, difficult deglutition, diarrhœa, and rapid emaciation. This form is invariably fatal in from three to fourteen days.

Chronic glanders has an insidious origin. The symptoms are: Chronic nasal catarrh, with discharges, which later become less sticky and yellow, and temporarily sanious, these hæmorrhages from the small ulcerous erosions being frequently the first visible sign. Later on nodules, and finally ulcers, appear on the nasal mucous membrane, and swelling of the submaxillary glands follows. Frequently there is cough and dyspnœa, and generally some irregular fever; wasting is marked, and in the late stages there may be œdematous swellings of the limbs, abdomen, and chest.

Glanders of the skin is less common in chronic glanders than in acute, the favourite sites being the limbs, shoulders, breast, and hypogastrium. The nodules or boils vary from a pea to a walnut in size, and may disappear to some extent, although they generally undergo change into ulcers; the efferent lymph vessels are swollen into knotted cords, the heads of which often become ulcerated ("farcy buds"). Affected lymphatic glands are often enlarged, and later become indurated or suppurate.

In a post-mortem examination, the nasal mucous membrane shows nodules varying in size from a grain of sand to a millet-seed, of gelatinous condition and grayish colour, and surrounded by a red ring. Ulcers also are

seen, which are sometimes covered with a brownish crust, resulting in radiating, star-shaped cicatrices. Similar conditions may be found in the lungs; and in the skin the cutaneous nodules vary in size from a hemp-seed to a pea, while in the subcutis the nodules may reach the size of a hen's egg, and may form abscesses. Of the other organs, the spleen is most frequently affected.

In man the disease is set up by direct inoculation of the infected secretions, usually into an abrasion of the skin. The parts usually infected in man are the hands, the nasal mucous membrane, the lips, and conjunctivæ. Infected parts become swollen and painful, and the lymphatics inflamed; there is fever, nasal discharge, ulcers on the nasal mucous membrane, pustules and abscesses in the skin, ulcers in the mouth, pharynx, and larynx, and on the conjunctiva; articular swellings are often present, and sometimes intense gastro-enteritis. As a rule, death ensues in from a fortnight to a month, or the disease may become chronic. The fatality is great unless the disease is strictly localized, and is treated early by cauterization.

The diagnosis is assisted by the inoculation of other animals (field-mice and guinea-pigs) for the observance of symptoms, and by the injection of "mallein."

"Mallein" is a preparation made from the bacilli of glanders. It is injected subcutaneously at the base of the neck, after the animal's temperature has been taken. The increase in temperature should exceed 2° C. for a certain diagnosis, and 1·2° C. to warrant suspicion.

The preventive measures which should be taken against the disease have generally been restricted to those embodied, as in 1892, in an Order of the Board of Agriculture. That Order provided for compensation for the slaughter of affected and suspected animals, and

certain powers were given for securing the examination of horses by veterinary surgeons, and for controlling the disease when discovered. Dead bodies were ordered to be buried 6 feet deep in their skins, and covered with a sufficient quantity of quicklime or other disinfectant; or the local authority was empowered, with the consent of the Board, to have the body, which had been disinfected prior to removal, cremated or treated by chemical agents.

Complete measures of prevention and stamping out would include: (1) A systematic and repeated inspection of horses in affected localities, and the employment of "mallein" for diagnostic purposes; (2) the avoidance of common drinking troughs; (3) the prompt separation of all suspected horses and the slaughter of all diseased ones; (4) the prompt cleansing and disinfection of infected premises; and (5) newly-purchased horses to be quarantined before being introduced into a stud.

A Departmental Committee, which reported on glanders in 1899, made the following recommendations:

1. That the Board of Agriculture should exercise a more extended supervision of the working of the Glanders or Farcy Order.

2. That notification should be made either to a constable or to a veterinary inspector.

3. That where practicable the local veterinary inspector should not engage in private practice.

4. That it should be made obligatory for veterinary surgeons to notify cases of glanders of which they become aware.

5. That occupiers or owners of knackers' yards should notify any case of glanders found in animals taken to their yards for slaughter.

6. That horses that react to the mallein test should be considered as possible sources of infection.

7. That horses that the veterinary inspector may consider to have been exposed to contagion should be dealt with in the same manner as suspected horses, but with certain reservations.

8. That the slaughter of all animals showing clinical symptoms of glanders should be made compulsory.

9. That compensation for horses slaughtered solely on account of reaction to the "mallein" test should be on a higher scale than that for a "clinical" diseased horse.

Variola.

Variola occurs in most of the domestic animals. Cow-pox (variola in the cow) was first transmitted to man, in 1796, by Jenner, who proved, in 1798, that it conferred immunity from small-pox. The close relationship existing between the various kinds of variola found in man and other animals is proved by their reciprocal power of conferring immunity. Cow-pox in man is protective against small-pox, and the latter is also protective against the former.

The symptoms of variola in animals, which appear after an incubation period of about a week, are divided into several stages: (1) The prodromal stage, which lasts a day or two, is characterized by fever, catarrhal affection of the mucous membranes, and erythema of the skin; (2) in the eruptive stage, lasting from six to eight days, red spots suddenly appear, which become nodules of the size of a pin's head, surrounded by a red ring, and which after a few days form bluish-white vesicles, often with a depression in the centre; (3) in the stage of suppuration, which lasts two or three days, the vesicles become pustules, and the temperature, which had fallen during the eruptive stage, again rises; (4) in the stage of exsic-

cation, which lasts from three to five days, the pustules dry up into yellowish, and later on into dark brown, crusts or scales, which fall off, leaving shining red cicatrices.

Sometimes the eruption is confluent, and the type of the disease may also be hæmorrhagic.

Cow-pox chiefly attacks young cows, the eruption being generally confined to the teats and udder ; fever is absent or slight ; and the prognosis is very good. The disease spreads slowly in a shed from animal to animal, and the eruption lasts altogether about twenty-one days.

The lymph of cow-pox, or "vaccine," was introduced for vaccination in man by Jenner in 1798. As cow-pox is comparatively rare, "humanized" vaccine, or vaccination from man to man, was subsequently employed ; but owing to the risks attending this practice, animal vaccination has been recently reintroduced. For the cultivation of the vaccine, calves five to twelve weeks old are taken, the skin over the lower part of the abdomen is shaved and disinfected, and the mature lymph from a previously vaccinated calf is inoculated. Vesicles mature in from four to five days, and the lymph collected from these is used for human vaccination, or for the further inoculation of calves. One calf yields from 1,000 to 3,000 doses of lymph. The vaccine may be preserved in (1) capillary tubes, in which it loses strength and becomes inert ; or (2) it may be kept in the dry condition by scraping off the lymph and crusts, drying them, and then placing them between two glass slides and sealing with paraffin—the vaccine then keeps for months ; or (3) it may be rubbed down with glycerine and preserved in capillary tubes.

Scarlet fever is said to affect the lower animals, but this is probably due to a confusion of the disease with petechial

fever—a disease characterized by hæmorrhages in the skin and internal organs, such hæmorrhages in the skin varying in size from a pea to a half-crown piece.

Scarlet fever in man has probably no sort of relation with any disease of cows. Klein's statements as to the relation between human scarlet fever and a bovine eruptive fever have never been confirmed, and cows are proved to be absolutely immune to human scarlet fever (Crookshank, McFadyean, Edington, McCall, Axe, and others).

Bubonic plague may affect rats, pigeons, mice, cats, monkeys, and pigs; and flies may communicate the disease.

The *cholera* of birds (fowl typhoid), swine *erysipelas*, *swine fever* or *hog cholera* or *hog typhoid*, *epidemic pleuro-pneumonia* in horses, bovines, and goats, *cattle plague*, *splenic apoplexy*, and *quarter ill*, have not been shown to be communicable to man.

Whether the *dysentery* of cattle and domestic animals, the *influenza* of horses, asses, and mules, and the *diphtheria* of birds, calves, and pigs, are etiologically identical with the similarly termed diseases in man is at present unknown, but the balance of evidence is opposed to such a view. The disease called "*thrush*" in human beings is found in calves, foals, and birds, and is due to the same fungus.

The Prevention of Communicable Diseases.

In the olden times epidemic disease was either regarded as the result of witchcraft or as a visitation from the Almighty, according as the mind of the observer was philosophically inclined to look to all human events as the result of the interposition of an

omnipotent power working for the evil or for the good of the human race.

A more exact knowledge of the causes of disease enables us to attribute contagious diseases, whether occurring epidemically or not, to the regular workings of natural laws in a definite and established order of sequence. Knowing the causes, it is not difficult to devise means to prevent the spread of contagious disease by, so to speak, throwing out of gear the natural sequence of events in their propagation.

In the first place, the *susceptibility of the individual may be modified*—(1) by protective inoculations which inhibit the growth of the specific organism, should it at any time gain an entrance into the body. At the present time protective inoculations of this description are only feasible in the case of small-pox, diphtheria, tetanus, rabies, anthrax, and possibly Oriental plague and Asiatic cholera. In the not remote future it may be expected that such inoculations will become possible for all the contagious diseases. But whether it will be desirable that such a practice should become general must necessarily depend upon the risks to health or life attaching to it, upon the chance of suffering from the disease in point to which the individual is exposed, and upon its severity when contracted. The practice of vaccination is sound, because small-pox is a disease of universal occurrence, from which few unvaccinated persons can hope to escape, and is especially fatal and severe in its effects. But no one not especially exposed would think of being inoculated for diseases of such rare occurrence as anthrax or rabies. (2) The susceptibility of the individual to tubercle, erysipelas, epidemic pneumonia, diphtheria, hospitalism, ophthalmia, may be decreased by measures which promote the public health

—by good drainage, by pure air, by pure water, by sufficiency and wholesomeness of food, and by unpolluted soils.

Such measures may be regarded as actually preventive of yellow fever, cholera, enteric fever, dysentery and diarrhœa; and they are most effective in modifying the incidence and severity of the specific eruptive fevers.

In regard to this last class, which occur for the most part in regularly recurring epidemics, it is of the greatest importance that the epidemic should be stamped out at the first onset, before the infection has had time to become widely spread. This can only be attained by a system of *compulsory notification* of all infectious diseases to the sanitary authority of the district. It will then generally be possible to isolate the first case or cases of the disease as they occur, to destroy the infection already generated, and to control the movements of the individuals with whom the sick person may have come into contact. Without compulsory notification, it must almost necessarily happen that the disease obtains headway before it is recognised, and then the most persevering efforts too often fail to obtain such a control as will prevent its widespread dissemination.

There are many who are in favour of a greater extension of the range of notifiable diseases, and would advocate the notification of influenza, cerebro-spinal fever, dysentery, ague, remittent fever, glanders, syphilis, septicæmia, purpura, tuberculosis, pneumonia, and acute rheumatism. As preventive measures are not limited to the control of infective diseases, good results might follow, and much valuable knowledge would accrue by the adoption of some system of compulsory notification of non-infectious illness, such as is now advocated and already practised in some European countries.

The *isolation* of all cases of contagious disease must be regarded as a most desirable measure, but is absolutely indispensable in the case of the epidemic diseases with air-borne contagia, if it is hoped to limit their spread. The same applies to the septic contagious diseases of hospitals. Tubercular diseases are rarely isolated, but it is probable that such a measure would have a considerable effect in limiting their spread. The more usually inoculable diseases—with the exceptions of leprosy, where segregation of the sick should be rigidly enforced, and of contagious ophthalmia—do not seem to demand measures of isolation.

Any attempt to prevent the importation of a disease into an unaffected country by *quarantine*—most usually resorted to to exclude Asiatic cholera, yellow fever, plague, or other Oriental diseases—is not in this country regarded as useful. The interference with commerce and national intercourse, the horrors to which the detained persons are exposed in quarantine camps or on board ship with fever or cholera raging during their period of seclusion, and the uncertainty attaching to the period of incubation and its maximum duration in these diseases, are all reasons why the enforcement of rigid quarantine has given way to the more humane and rational system of isolation of the sick as soon as they arrive on the frontier or (in our case) seaboard, and of disinfection of the infected articles and of the whole ship, with observation of the movements of all the persons who leave the ship for the period of a fortnight or longer.

The isolation of the sick should invariably be enforced in cases of small-pox, typhus, scarlet fever, diphtheria, measles, and whooping-cough, and this can most thoroughly be carried out by the removal of the patient to an infectious disease hospital. A difficulty arises in

the case of measles that the pre-eruptive stage is infectious, and that before the isolation can be effected other persons have probably caught the infection. In measles and whooping-cough also, the contagion is so diffusible and universal that few can hope to escape; and the tender age of the sufferers in these and other infantile complaints renders them less suitable for hospital treatment than is the case with older children and adults.

Where removal to hospital is not feasible, isolation must be attempted by placing the patient in a room by himself at the top of the house, all communication with the other inmates being forbidden; and the aerial connection between the sick-room and the rest of the house must be broken as much as possible by hanging up outside the door a sheet kept constantly soaked with some disinfectant liquid. Nothing must be allowed to pass out of the sick-room unless previously disinfected, and all dressings, poultices, and rags should be immediately burnt after use.

Schools.—Among the means of spreading infection by personal communication, compulsory school attendance, affecting as it does the most susceptible period of life, occupies a prominent place. At the present time we are dependent in our efforts to prevent the spread of infection in schools on (*a*) the compulsory information supplied under the Infectious Disease Notification Act, and (*b*) on the voluntary information supplied by teachers and others, as to measles and whooping-cough, in the districts where these diseases are not notifiable compulsorily. It is now usual for the Medical Officer of Health, on the receipt of a notification of a case of infectious disease in the person of a child attending school, to inform the school authorities of the case, so that all children in the same house attending school

may be excluded, until the premises are declared free from infection. If the child attacked is removed at once to an isolation hospital, the room, clothes, and bedding can be at once disinfected, and the other children may be allowed to return to school on the expiration of the number of days corresponding to the maximum incubation period of the disease in question. If the child attacked is kept at home during its illness, the other children in the house must be excluded from school during the whole period of illness until the recovery of the patient, and the disinfection of its room and belongings. The diseases for which these precautions are especially necessary are small-pox, typhus, diphtheria, scarlet fever, measles, and whooping-cough. The two latter, however, are not usually notified to sanitary authorities, not being included in the Infectious Disease Notification Act of 1889. The same precautions are obviously necessary, moreover, where the case notified is not that of a person attending school, but where children attending school occupy the same house.

On its becoming evident to the Medical Officer of Health of a district, that an epidemic of scarlet fever, diphtheria, or measles is threatened, or is being maintained by the opportunities afforded for personal infection owing to school attendance at public elementary schools, and that no other less drastic measures will suffice for the suppression of the epidemic, it is his duty to advise his sanitary authority to exercise its powers under Article 88 of the Education Code (1890), to compel the closure of one or more of the public elementary schools for a specified time. Such measures are especially useful in rural districts, where school is often a centre where children from scattered hamlets meet, who would not otherwise be brought into contact with each

other. In towns, school closure is often less efficacious in eradicating an epidemic, as the children when not at school are liable to meet in the streets for play, or in each other's houses, and thus propagate infection. At the same time, it is clear that infection is less likely to be imparted in a wholesale manner under these conditions than under the conditions of close crowding and inefficient ventilation prevailing in most Board schools. It may also be necessary to obtain the closure of Board schools for defective sanitary arrangements, which appear to have some connection with illness such as enteric fever, diarrhœa, or diphtheria, occurring amongst the scholars.

To enable a decision to be arrived at as to what extra measures are called for, in order to reduce the spread of infection at schools, it is necessary to appreciate the fact that a larger part of the spread results from undiagnosed mild cases, attending school, than from children resuming school attendance too soon after the disease has been diagnosed and treated. The measure which has met with most favour, and which is in actual operation in Germany and in America, is to submit the scholars to repeated medical inspections. These inspections should be performed by a medical man appointed to each district, who in non-epidemic times will examine the scholars, say twice a year, with the view of detecting those numerous conditions which unfit a scholar temporarily for school attendance, or which require early correction, such as developmental defects, faulty vision, overpressure, and other diseased conditions not necessarily infectious. He should also be able to make a prompt examination of every pupil referred to him at any time by any teacher, and should lecture to and instruct the teachers upon the symptoms of disease in

school-life. During exceptional prevalence of communicable disease he should make frequent, and sometimes daily, inspection of the scholars in the schools allotted to him. All suspicious cases should be excluded from school, and after diagnosis should be handed over to the care of their regular medical attendant, when such exists.

Small-pox.—In this disease, in addition to the usual precautions, it is most desirable to have all the invaded inmates of the house vaccinated or revaccinated. Removal to hospital should be insisted on; and in those towns where compulsory vaccination of infants is in disrepute, and not rigidly enforced, quarantine stations should be established by the local authorities, where the inmates of the affected house can be received and thoroughly isolated for a time corresponding to the maximum incubation period of small-pox, board and lodging being of course gratuitously provided.

Hospitals.

The aggregation of a large number of sick persons suffering from a variety of diseases, or recovering from surgical operations, in one common building is a necessity of modern life, but is now recognised as being often attended with risks and dangers from which the patient treated in his own home is to a large extent exempt. In former times this crowding together of the sick in hospitals led to outbreaks of erysipelas, pyæmia, and hospital gangrene in the surgical wards, the contagion appearing to be conveyed from one patient to another through the air, or by means of the surgeon's hands or instruments when engaged in dressing wounds. The antiseptic treatment of wounds and injuries, and the

greater care bestowed on the construction and management of hospitals, have nearly eradicated these terrible diseases from modern hospital practice; but when from any cause the surgical wards of hospitals are overcrowded, and the cleanliness and frequent dressings of wounds cannot be attended to, these septic diseases are almost sure to make their appearance and cause frightful havoc.

It has often been noticed that cases of open wounds from injury or operation recover far more rapidly when treated in the open air, or in huts and tents practically open to the air, than when confined in close buildings; and the same is true of cases of acute infectious disease. For such cases the breathing of pure air is a prophylactic worth more than all the drugs in the Pharmacopœia. For the cases of organic disease of important viscera, which are treated in medical wards, the beneficial effects of pure air, though not equally striking, are not unimportant, although in these cases pure air and thorough ventilation must often be subordinated to considerations of warmth and moisture.

The first principle, then, in hospital construction and management is bound up in an abundant supply of pure air to the patients. The putrescent organic effluvia from the skins and lungs of sick persons, which, if not more copious, are certainly more deleterious than those from healthy people, must be diluted with fresh air and rapidly carried away. For each patient in a medical ward, the superficial floor space should not be less than 100 square feet, and the cubic space 1,000 cubic feet. The air should be changed at least three times in an hour, which would give 3,000 cubic feet of fresh air per head per hour. In wards containing many patients suffering from phthisis, bronchitis, or pneumonia, with

much purulent expectoration, a higher set of figures should be taken.

For surgical wards and infectious disease hospitals the minimum floor space should be 144 square feet, and the minimum cubic space 2,000 cubic feet per head, changed three or four times an hour. The window surface should be in the proportion of 1 square foot to about every 70 feet of cubic space. In the surgical wards, the effluvia from purulent or septic wounds are added to the exhalations from the lungs and skin, and require rapid dilution and removal. In the infectious wards, infective particles are wafted into the air from the skin and excretions, and must be destroyed by thorough oxidation as soon as formed.

For general hospitals it is found that the most convenient number of patients that may be treated in one ward is on an average 30, this being the number which one nurse can readily supervise. In an *oblong ward* (Fig. 85) with thirty patients, each patient to have 100 square feet of floor space and 1,000 cubic feet of air space, 3,000 square feet of floor space will be required and 30,000 cubic feet of air space. The 3,000 square feet of floor space will be available if the ward is 120 feet long and 25 feet wide. As there are 15 beds on each side of the ward, the longitudinal wall space for each bed will be 8 feet, and the distance between any two beds (themselves 3 feet wide and 6½ feet long) will be 5 feet. The width of 25 feet is a convenient one, as it allows a passage 11 feet wide between the two rows of beds for the whole length of the ward, and permits of thorough cross-ventilation between the opposite windows, and the flooding of every part of the ward with daylight.

To provide the 30,000 cubic feet of air space the ward

must be 10 feet high. It would be better to have the height of the ward 12 feet, which would allow 1,200 cubic feet of air space per patient. Any height above 14 or 15 feet is useless for purposes of ventilation, and should be discounted in calculating the cubic space per head.

The *circular ward* system (Fig. 85) has been much advocated. It has several advantages, such as the

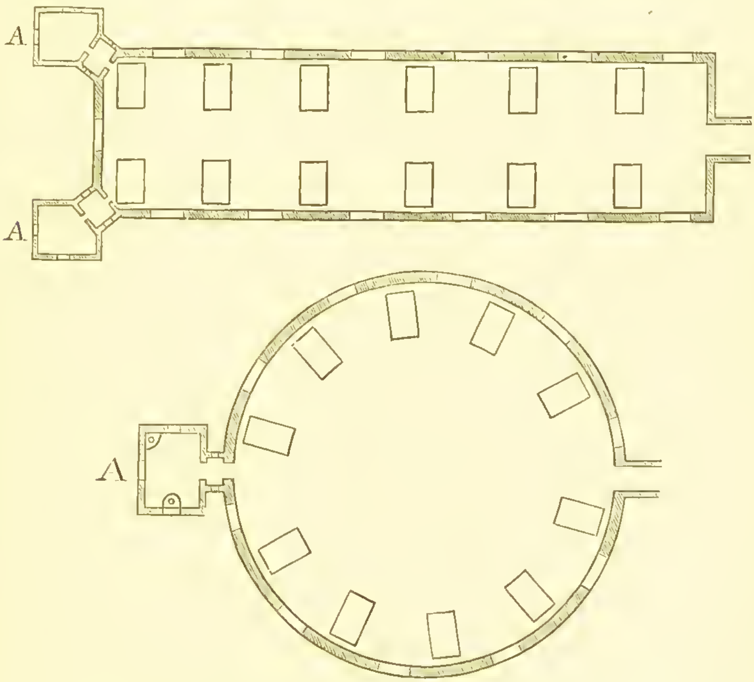

FIG. 85.—DIAGRAMS OF OBLONG AND CIRCULAR WARDS.
A, Turret blocks for water-closets, baths, and sinks.

absence of corners for the accumulation of dust, the aspect facing all corners of the compass, by which the ward obtains sunlight at all seasons of the year and at every hour of the day, and the facility offered to nurses and attendants in passing from one bed to another. On the other hand, if a circular ward is to accommodate the same number of patients as an oblong ward, having

an equal floor measurement and cubic contents, the beds of the patients, which are placed around the wall, must be very closely packed together, and the 8 feet of wall space per head cannot by any possibility be attained.

Thus, for a circular ward to have 3,000 square feet of floor space, the diameter of the circle must be 61·8 feet. The circumference of the circle will be 194 feet. From this must be deducted the width of the entrances of two lobbies or passages, say 13 feet, which leaves 181 feet of wall space for thirty beds, or about 6 feet per bed at the head of the bed. The circumference of the smaller circle formed by the feet of the beds is 153 feet, which gives 5 feet per bed at their feet, or an average of 5·5 feet for each bed. This means far too close approximation of the beds, and the creation of an evil not encountered in the oblong wards. There is a large open space in the centre of the ward unoccupied, which is of little use to the patients crowded together at the circumference. It has been proposed to utilize this space for a nurses' room or for a central staircase; but both these plans would create obstruction to cross-ventilation and access of light, whilst the central staircase might act as a shaft for the passage of foul air from one ward to another.

Where space will admit, the system of one-storeyed pavilions is far the best for all hospitals, and is especially suited for those intended for infectious diseases. The pavilions are connected with one another and with the administrative blocks by corridors which are, or may be, open to the air; and all risk of transference of foul air and effluvia from one ward to another is avoided. In large towns a certain amount of crowding on a limited area is indispensable, and wards of two or more storeys in height must be built. Even in these, the system of

disconnected pavilions should be aimed at, and the staircases require careful planning to prevent them acting as shafts for the passage of air from one ward to another. The external air space around the wards should be ample, and overshadowing by high buildings in the neighbourhood must be carefully avoided.

Provision should be made for the entrance of warmed fresh air in winter; this may be effected by Galton's ventilating open fireplace, or by a ventilating stove or stoves placed in the centre of the ward. Hot-water pipes should also be placed in the ward, as they may be required during very cold weather, or for the treatment of cases where much warmth is desired. They should be placed in a position convenient of access for cleansing any space behind or below them, and should not be fixed in channels or chased recesses in walls or floors.

To secure the best kinds of natural ventilation, the ward should have opposite windows reaching nearly to the ceiling, and the upper portion of each window should be made to revolve on its lower border into the ward, so as to admit fresh air during warm weather in an upward, slanting direction. It is also very desirable to have an inlet for fresh air, which can be warmed in winter, close to the floor at the head of each bed, in order to ventilate the space under the bed, and at once carry away the respired air and effluvia from each patient. For the escape of the heated and vitiated air, there should be numerous extraction shafts opening near the ceiling, which should be joined together, the single shaft so formed being then carried up in close contact with the stove or chimney-flue, in order that the column of air in it may not be allowed to cool and hinder the up-draught. In summer, when the stoves are not

in action, the same result may be produced by burning gas in Bunsen burners at the bottom of the extraction shafts.

In the ventilation of hospital wards, the "propulsion" or "plenum" method is regarded with favour, because when air is propelled into a building the source of supply can be chosen, the air can be cleansed, warmed, and brought to a suitable hygrometric condition. The chance of infection being carried aerially from ward to ward is lessened, from the circumstance that the air-supply to each ward can be kept quite distinct and separate. There is, however, one condition essential to the success of the "plenum" system of ventilation, which is generally regarded with disfavour, viz., that the movement of air must be kept absolutely under control, and consequently that the opening of windows cannot be permitted. The General Hospital at Birmingham is ventilated by this system. In this building the main air-ducts are carried under the corridors, from which separate flues are carried up to the several wards, the air outlets being at the floor level. The vitiated air is carried away through ventilating turrets at the ends of the wards. Where an extraction system alone is relied upon, the entering air is incapable of regulation, both as to its source and its amount.

The water-closets, bath-rooms, and slop-sinks should be placed in a block outside the ward, but connected with it by a cross-ventilated lobby (Fig. 85, *A*). By this means, if disconnection of waste pipes and ventilation of soil pipes are properly attended to, there is no risk of foul drain air gaining access to the ward. Proper hospital slop-sinks are necessary for washing and emptying bed-pans, spittoons, and urine slippers. They should be made of porcelain or enamelled fire-clay, should be of

large size, at least 15 inches square at the top, and should be flushed from a water-waste preventer.

Almost as important as good ventilation is the provision of internal surfaces (walls, floors, and ceilings) to the wards, which will not hold or absorb organic effluvia. The occurrence of erysipelas and surgical fever has been attributed—and probably rightly so—to wooden floors with chinks and crevices between the boards. The organic matters from poultices and dressings find their way into these crevices, and accumulate under the flooring.

The floors of the wards should be covered with oak parqueterie, or with solid wood-block flooring without chinks or cracks, laid on a bed of concrete. The surface should be painted, or stained and varnished, and kept clean without washing. The parqueted floors should be oiled and beeswaxed, or melted paraffin may be ironed into the woodwork, which it penetrates for about $\frac{1}{4}$ inch, forming an unbroken surface, which remains good for years. It is most essential to avoid washing floors with water. The air of the wards is by this means chilled from evaporation when the floor is drying. All cornices, corners, and ledges should be avoided in the wards, and all angles rounded off, so as to offer every facility for cleansing.

The wall surfaces should be impermeable. Glazed brickwork or glazed tiles set in Portland cement afford, perhaps, the best and most easily cleaned surface. But the walls may also be coated with cement and paint, or even distempered if tiles are too costly. Ceilings may be cemented, or lime-washed several times a year.

The bedsteads should be of iron, with spring wire mattresses, and in the surgical wards provided with

movable fracture boards. It is very important to reduce the furniture of the ward to a minimum, and to allow no curtains, hangings, or drapery of any sort.

Excreta, sputa, dirty dressings, and poultices must be removed from the wards at very frequent intervals. In the case of infectious disease hospitals, it is very desirable that these refuse matters should be destroyed. This can be done by means of a small destructor furnace in connection with the boiler-house or heating furnace of a large hospital.

No harm has been shown to result from allowing the drains from a fever hospital to empty into the public sewer, or from the slop waters being disposed of by sub-irrigation.

For the exercise of the patients, covered balconies on the southern or western aspect of the building should be provided ; and in large towns, where space for a garden is wanting, a flat roof affords a valuable exercise and recreation ground.

In some of the more recently-constructed hospitals, it has been found convenient to place the kitchens and sculleries at the top of the building, and to use gas and steam for all culinary purposes.

Every town should have hospital accommodation for the isolation of cases of infectious disease. The amount of accommodation required will depend upon the character of the population ; but it may be stated generally that there should be at least one bed to every 1,000 of the population, when this is largely composed of the industrial classes. The one-storeyed pavilion system is most suitable for infectious disease hospitals ; and separate pavilions should be set aside for the separate accommodation of each different disease to be treated. A site should be chosen outside the town, in a thinly-populated

neighbourhood, with a southern exposure, a good fall for drainage, and easy of access from the town. The best arrangement is to place the pavilions on a north and south line, with easterly and westerly aspects, so that every side can receive sunshine.

In epidemic periods it may be necessary to supplement existing hospital accommodation, and for this purpose tents (in summer) or huts of galvanized iron, wood, Willesden waterproof material, or Dœcker's material (a waterproof composition resembling leather), can be erected. Huts of the three last materials are preferable to iron, as they are easier to warm. The floors should be raised a foot from the ground, and the ridge of the roof should be used for ventilation as well as the windows. If these huts are constructed with hollow walls, the temperature in cold weather can be properly maintained with efficient ventilation—a difficult task without hollow walls, owing to thinness of the materials. As the wood and waterproof compositions used in the construction of these hut hospitals are liable to rot and decay, they can only be regarded as temporary structures, and as soon as the emergency which necessitated their erection is over, they are best pulled down and destroyed.

As the late Sir Richard Thorne pointed out, the provision for isolating infectious cases is best carried out with deliberation in non-epidemic periods. A memorandum of the Local Government Board states that in a village a small cottage, capable of isolating four cases in two separate rooms, should at least be provided; but a minimum in other cases should be four small permanent wards of brick, stone, or concrete, this accommodation being capable of being extended, if need be, by tents or huts. It is never desirable to accommodate more than twenty persons per acre, and the hospital buildings should

always be 40 feet from the boundary fence. Temporary (wood and iron) hospitals are not approved of by the Local Government Board; for if these are constructed so as to insure a fairly equable ward temperature, the cost is about the same as that incurred in the erection of ordinary brick buildings, while they are less durable and more expensive to keep in repair. Moreover, wooden lined wards are not adapted to the varying needs of a permanent building, and the risks from fire are very great in such wooden structures. Extemporized hospitals, erected to meet the demands of a sudden outbreak, are often not ready for occupation until the immediate cause for their erection has passed by, and they provide accommodation of a very indifferent sort.

Certain general regulations must be observed in all fever hospitals. No member of the staff must leave the premises without first changing the outer garments; tradesmen must never be permitted to pass beyond the boundary wall or fence; the visits to the patients should be limited to the nearest relatives and the most intimate friends of those patients who are dangerously ill, and then one visit only of fifteen minutes' duration should be sanctioned each day; all visitors should be made to wear overalls on entering the ward, and to wash their hands and faces on leaving ; they should also be warned against entering any public conveyance immediately after quitting the ward.

CHAPTER X.

DISINFECTION.

As already mentioned, the virus of a contagious disease undergoes enormous multiplication in the body of the sick person, and is cast off during the period of illness in the discharges and secretions, in the breath and from the skin. The contagion infects the air around the patient, and infects the clothes and furniture of the sick-room. Disinfection aims at the destruction of the virus in these various situations.

In the first place, it would be natural to suppose that the infective particles might be destroyed before leaving the body, or as soon as they are carried into the air. But except in the case of scarlet fever, where inunctions of carbolized oil to the surface of the body may prevent the desquamating skin acting as a source of infection, it is evident that chemical reagents strong enough to destroy specific micro-organisms would cause injury when taken into the system, or when diffused into the air around the patient. Where the virus is only contained in the evacuations, as in enteric fever, these can be at once disinfected by chemical solutions; but in the case of the other common infectious maladies complete disinfection is only possible when the patient is convalescent and no longer a source of infection himself.

No agent can be regarded as a *disinfectant* unless it is capable of destroying the organisms with which it is brought into contact; agents which merely inhibit bacterial growth and prevent decomposition, being less powerful than disinfectants, are known as *antiseptics;* while others, such as charcoal, which oxidize or absorb odorous products, are termed *deodorants.* Liquid disinfectant preparations are preferable to solid, for they can be much more efficiently distributed; and until a solid disinfectant is in solution, it is powerless to act directly upon organisms. No gas or vapour, employed at the current temperature and pressure of a dwelling-room, possesses such powers of penetration as would make it an efficient disinfectant of textile fabrics. The final results attained in disinfection are greatly influenced by the nature of the material to be disinfected. Infectious organisms are always in association with a greater or less amount of other inert matter under natural conditions; and the practical question which has to be answered is: What is the required strength of any disinfecting agent to insure destruction of a given infection in its natural environment?

Disinfection may be carried out in several ways:

1. By exposure to high temperatures (fire, hot air, steam, boiling).

2. By the action of oxidizing agents (atmospheric air, ozone, nitric peroxide, peroxide of hydrogen, chlorine, chlorates, bleaching-powder, etc.). Oxygen burns up all organic matter into carbonic acid, ammonia, and water; it exercises no selective influence on bacteria. Certain organisms die at once in atmospheres containing oxygen; some cannot exist in the absence of oxygen, while others are indifferent either to its presence or absence.

Fresh air is universally regarded as a powerful if slow

disinfectant. Its powers in this respect are mainly due to the molecular oxygen contained in it; if, however, oxygen can be liberated in a nascent atomic condition, its activity considerably exceeds that of atmospheric oxygen. The disinfectant properties of fresh air are enhanced by the actinic rays of sunlight. Rays of sunlight, in the presence of air and moisture, will destroy even resistant organisms after varying periods of exposure; but there is no evidence of the destruction of the spores of anthrax bacilli by this means. The actinic rays probably exert their effects by promoting oxidation, or possibly by leading to the production of small quantities of ozone and peroxide of hydrogen—two powerful oxidizers. The ultra-violet rays are much more powerful in this respect than the infra-red.

3. By the action of reducing agents (sulphurous acid, ferrous sulphate, etc.).

4. By agents which enter into combination with albumin (perchloride of mercury, sulphate of copper, etc.). These kill by their action on the albumin of the organism; or, by precipitating the albuminous matter around the germ, they may rob it of its nourishment.

5. By agents which exercise a direct poisonous effect on micro-organisms (perchloride of mercury, iodide of mercury, phenols, etc.).

Deodorants act by absorbing (slaked lime), condensing (carbon), or oxidizing (permanganate of potash) odorous gases or vapours, such as sulphuretted hydrogen, ammonia, the compound ammonias, and some organic vapours. Many deodorants (carbon, permanganate of potash, etc.) possess little, if any, disinfecting power.

Having regard to the circumstances of actual practice, it may be said that no disinfectant can be expected to act instantaneously, for it cannot be brought to bear in

sufficient volume upon all the organisms to which it is applied; hence the agent should possess some degree of permanence in its action. Those disinfectants, for instance, which, by giving up oxygen, soon expend themselves in contact with organic matter are inferior to substances like carbolic acid, which have greater permanence of action, and exert a direct toxic effect upon organisms. In practice, no agent of the kind which does not perform its functions within a limit of about thirty minutes can be regarded as satisfactory. Preference should be given to one which is non-poisonous to the higher forms of animal life, cheap, readily soluble in water, and otherwise convenient in use.

Burning.—This, the most efficient means of disinfection, can be applied, often in the sick-room itself, to all articles of little or no value. Rags used for receiving the discharges from the mouth and nose, or from the open wounds of patients in an infectious state, should be promptly placed upon the fire, before they have time to become dry. Old mattresses, pillows, and other large articles which are not required for further use should be saturated with paraffin and burned. This is generally done in the small destructor which forms part of a disinfecting-station. The stools of cholera and enteric fever patients may be cremated; if no destructor be available for the purpose, they must be mixed with plenty of sawdust, and the mixture then saturated with paraffin and ignited.

Boiling.—Infectious material which can be boiled for twenty minutes is thereby as a rule efficiently disinfected; but there is evidence that some of the more resistant organisms (*B. tuberculosis*, *B. anthracis*, and the *streptococci* of *puerperal fever*) may resist boiling for longer periods. This method is most frequently employed for

the purpose of disinfecting bed and body linen. It is important to bear in mind that if the articles are stained with albuminous matter, such as blood or fæces, the boiling tends to fix the stains; on this account the stains should first be removed by soaking in cold water, and, if necessary, by rubbing with a little soap.

Hot Air.—This method of disinfection is rapidly falling into disuse; for the high temperature required to destroy resistant organisms injures the articles exposed, and an inconveniently long period of exposure is necessary to secure sufficient penetration of the heat into the interior of bulky objects. Dry air being a bad conductor, the heat penetrates slowly and imperfectly. Resistant bacteria placed in the interior of mattresses may survive an exposure of some three hours, even when the temperature to which the surfaces of the mattresses are exposed reaches 140° C. A temperature exceeding 120° C. would certainly damage many articles, such as wool, leather, and silk. By this method, therefore, fabrics are often damaged by scorching; but, short of this, they are liable to suffer a change in colour, to shrink, and to lose elasticity and gloss. Stains, especially those of an albuminous nature (blood, fæces), are liable to become fixed, but these can always be removed prior to disinfection by soaking and subsequent rubbing in cold water. Fusible substances, such as glue and wax, are melted, and the overdrying renders many articles brittle.

In Ransom's well-known hot-air apparatus the oven is heated by gas, and the products of combustion mixed with hot air enter the chamber from below. A thermometer is attached to indicate the temperature of the oven; and a special device is used for guarding against fire, and also to prevent the temperature of the air from becoming excessively high. A link of fusible metal melts when the

temperature of the oven approaches 148° C., and by this means the gas-supply is mechanically cut off. The same device may be applied to an oven heated by a fire, the damper being made to shut off the outlet to the chamber, when the fire slowly dies out from lack of air to feed it.

Dry heat is serviceable for articles of leather, morocco, indiarubber, and fur, books, and some other objects, the gloss of which is lost, or impaired, by the employment of the more efficient method next to be described.

Steam.—Steam under pressure penetrates into bulky and badly conducting articles, such as mattresses, pillows, and clothing, far more rapidly than dry heat. As such steam penetrates into the interstices of a cold body, it undergoes condensation, and imparts its latent heat instantaneously to the cold objects in contact with it. When thus condensed into water, it occupies only a very small fraction (about $\frac{1}{1600}$) of its former volume. To fill the vacuum thus formed, more steam presses forward, in its turn yielding up its latent heat and becoming condensed, and so on until the whole mass has been penetrated. On the other hand, hot air in yielding up its heat undergoes contraction in volume only to a very small extent as compared with that undergone by steam in condensing to water.

Body lice and their eggs are destroyed by exposure to steam at 100° C. for ten minutes, or to boiling water for five minutes.

The various stoves now employed for disinfecting by steam may be classified as follows:

1. Stoves in which steam without pressure is employed. These are of course cheaper, but, as the temperature of the steam does not exceed 100° C., less efficient than—

2. Those in which steam at low pressure (2, 3, or 5

pounds per square inch) is used. Although the temperature of 110° C., which can be reached by these stoves, is generally sufficient, a higher temperature can never be employed in them. These stoves, though cheaper, are therefore less efficient than—

3. Those in which steam at high pressure (10 pounds and over) can be employed. A temperature of 115° C. to 120° C.—which should not be exceeded—can be obtained in these stoves; and an exposure of articles for from a quarter to half an hour will suffice for their disinfection. The higher the pressure of the steam, the more rapid the penetration, and the less time required for disinfection.

(*a*) The steam may be *current* or *confined*. There is an advantage in the use of current steam, for it serves to drive the air out of the interstices of fabrics, and thus to aid penetration; but since more steam is used, more fuel is consumed. In the stoves using steam confined under pressure, the steam should be allowed to escape from time to time, as this promotes rapid penetration, the sudden reduction of the pressure causing an expansion of the steam in the interstices of the material under treatment, and vaporization of the moisture contained therein, which displaces the air (otherwise often compressed) in the centre of bulky articles. The greatest effect is of course produced when the steam has been under very high pressure.

(*b*) The steam employed may be *saturated* or *superheated*, the former being far preferable to the latter, owing to its more rapid and thorough penetration. The use of superheated steam, therefore, involves a longer exposure in the chamber, and a greater expenditure of fuel, in addition to an increased liability to injure articles. The distinction between saturated and superheated steam is an im-

portant one. By increasing the pressure, steam may be generated at temperatures exceeding 100° C., but it always remains saturated steam ; if, however, the steam is further raised in temperature without increasing the pressure, as may be done by bringing it into contact with a surface raised above its own temperature, it becomes *superheated*. Now, superheated steam has the properties of a gas, and will not condense until it has parted with all its 'superheat' by the slow process of conduction ; whereas saturated steam, being a vapour, condenses at once on objects which are but slightly cooler than itself. Since penetration depends upon condensation, the disinfectant value of superheated steam does not much exceed that of dry air. The amount of 'superheat,' however, which is generally given to the steam in practice is not sufficient to cause it to act very differently from saturated steam.

Steam, therefore, should not be superheated, or only to so slight an extent that it can at once condense upon any object slightly cooler than itself.

The further requirements of a steam disinfecting apparatus are as follows:

1. Satisfactory provision must be made to insure that the infected articles are not allowed to become too wet, as otherwise colours are liable to run ; and the disinfected articles should be fairly dry on removal.

2. The steam, which should be free from air, should be quickly and uniformly distributed throughout the chamber at the maximum temperature required.

3. The apparatus must not be too expensive, either as to its first cost, its upkeep, or its working ; and its construction must be such as to combine simplicity of design with facility of management—so that highly-skilled labour is not an absolute essential.

The time required for disinfection by steam obviously

depends on the organism to be destroyed, the bulk of the infected articles, and the pressure of the steam employed. The best researches indicate a temperature of 115° to 120° C. for twenty minutes, as alone trustworthy in all cases.

By bearing the foregoing facts in mind, an opinion upon the suitability and efficiency of any steam disinfector can be readily formed. The rapidity of the penetration of heat into articles is ascertained by placing within them a thermometer, which on registering the required temperature rings a bell, by reason of the mercury completing the circuit of an electric current from a battery. The efficiency of the provision for drying the articles is gauged by the amount of moisture remaining in them after removal from the stove, as calculated by the increase in weight of the article. The maximum temperature reached in the stove and the uniform distribution of the heat may be tested by means of recently standardized maximum thermometers wrapped up in blankets and exposed in the stove; and the pressure within the stove can be ascertained at any time by the external pressure gauge.

The machines made under *Washington Lyon's* patents are most used in this country, and may be taken as types of such apparatus. They consist of a chamber, elliptical in section, with a double wall or jacket. Steam is admitted into the space between the double wall at a pressure of some 15 to 30 pounds; this serves to heat the walls of the chamber, and to a less extent the articles inside it, so that when the steam, at a pressure of some 10 to 20 pounds, is admitted into the chamber, the condensation, which would otherwise take place upon the walls of the chamber, is prevented, and only a slight initial condensation on the surface of the infected articles results.

Owing to the greater heat of the steam in the jacket, that in the chamber is slightly superheated, and articles are kept comparatively dry; but before they are removed they are further dried, either by allowing the steam to remain in the jacket, after that to the interior of the chamber has been cut off, or preferably by the use of hot air. By creating a partial vacuum in the stove, a current of hot air (heated by steam, so as to limit the temperature and guard against scorching) can be drawn into the chamber, and this much facilitates the drying of the articles. Steam exhausts are employed in some apparatus to produce a partial vacuum in the chamber prior to the admission of the steam, and these greatly promote, by the withdrawal of air, the rapidity of penetration.

The *Equifex Disinfector* is a non-jacketed cylinder, into which steam at a pressure of 10 pounds is admitted. The steam which first enters is allowed to blow off, so as to displace the air in the chamber; and the pressure of the steam can be intermitted so as to facilitate penetration. Condensation upon the walls of the cylinder is prevented by an arrangement of coils containing steam at high pressure; and articles are subsequently dried by hot air. A low-pressure apparatus is also made of the Equifex type.

Reck's Stove is a non-jacketed cylinder, in which steam is employed at about 1½ pounds pressure (about 105° C.), and therefore articles require exposure to it for at least one hour. The apparatus is very simple and handy. Its special feature is an arrangement for the introduction at the top of the chamber of a shower of cold water, which falls upon an umbrella-shaped plate, and is thus diverted from the articles which are being disinfected. The sudden introduction of the cold shower after the goods have been disinfected causes a rapid condensation of all

live steam, which is carried away with the water through an outlet in the bottom of the stove, air entering automatically through a valve in the front of the apparatus to restore the partial vacuum produced by the condensation of the steam. In this way the chamber is freed of the steam, and the articles are dried ; but the drying is not quite so complete as in most other forms of apparatus.

Thresh's Stove.—Here steam is employed, without pressure, at a temperature of about 105° C., the "superheat" being obtained by using in the boiler a calcium chloride solution, the boiling-point of which is considerably above that of water. The lower part of the jacket of the cylinder, which contains the saline solution, acts as the boiler, and is heated by a small furnace. The steam, which enters the chamber, escapes continuously through a chimney. For the subsequent displacement of the steam and for the drying of the articles, hot air is drawn into the chamber through a coil of tubes, which is surrounded and heated by the boiling solution.

Steam disinfectors are made portable, so that they may be taken to infected premises, or be moved from village to village. Their cost varies from about 60 to 150 guineas, according to the size.

The insufficiency of low-pressure apparatus depends less upon the fact that a sufficiently high temperature is not reached, than upon the circumstance that sufficient penetration is not assured. In all those apparatus in which steam is employed at a low pressure or in a superheated form (*i.e.*, at temperatures not exceeding 104° to 110° C.), objects should be exposed for at least one hour.

A *disinfecting-station* should comprise :

1. Two rooms completely separated from each other by a wall, into which the stove is built, so that it communicates with both rooms. The infected articles are

brought into one room and placed in the stove, and after disinfection they are removed from the other end of the stove, which opens into the non-infected room. No infectious material must be allowed to enter the non-infected room, and there should be no direct means of communication between it and the infected room. The floors and walls of both rooms should be made of some smooth and non-porous material, which can be readily and efficiently cleansed by water; and exceptionally good provision should be made for ventilation and light.

2. An incinerator or destructor, provided with a small second fire to cremate the products of imperfect combustion before they pass up the flue.

3. Separate sheds must be provided for (*a*) vans employed to bring in infected articles, and (*b*) those employed to return the disinfected articles.

4. A laundry and bath-room sometimes form part of a disinfecting-station, a charge being made for any laundry work undertaken.

Liquid Disinfectants.

Solutions of the following substances are employed:

Perchloride of Mercury ($HgCl_2$, Corrosive Sublimate).—This is one of the most powerful and one of the most convenient disinfectant agents known. It forms a colourless, non-odorous solution, which is poisonous to human beings and exerts a corrosive effect upon metals. Unless the solution is acidulated, it has a marked precipitating effect upon albumin, and its powers of penetration into the interior of particles of organic matter are thereby limited.

It acts as a direct poison to bacteria, and also exerts its disinfectant action by coagulating their protoplasm.

One part of the salt to 1,000 parts of water constitutes a stronger disinfectant than even 5 per cent. carbolic solution, and it is trustworthy for the disinfection of non-spore-bearing bacteria ; but 1 in 500 is preferable for spore-bearing bacteria.

The solution should not be stored in metal receptacles, as it corrodes them, and is then liable to decomposition. It should always be made distinctly acid, and a little colouring matter should be added to guard against its being swallowed in mistake for water. For the same reason it should be placed in dark blue bottles bearing a large poison label.

Half an ounce of perchloride of mercury, 1 ounce of hydrochloric acid, and 1 grain of aniline blue, to 3 gallons of water, is a mixture which costs about fourpence, and furnishes a non-staining disinfectant solution, containing about 1 in 1,000 of the perchloride.

The salt has been made up into tablets of about 1 ounce each in weight, so that one tablet to a quart of water furnishes a solution of 1 in 1,000 of the perchloride. This constitutes a portable form, convenient to travellers and troops on the march ; but there is risk in introducing the tablets, which look very like sweets, into ordinary households.

Mercuric Iodide (HgI_2) is less poisonous than the perchloride, and does not precipitate albumin to the same degree. Its disinfectant power is at least equal to, and there is evidence that it even excels, that of the perchloride. It constitutes an excellent disinfectant solution for the hands. Although insoluble in pure water, it is readily soluble in the presence of excess of iodide of potassium. Like the perchloride, it attacks metals.

Phenols are obtained from tar distillates as dark oily liquids, which contain in the crude state, besides the

many members of the group, the neutral tar oils. Phenols are poisonous, possess a caustic action, and coagulate albumin.

Carbolic Acid (C_6H_6O) is the member of the group most employed for disinfectant purposes, although its powers are slightly inferior to those of cresylic acid (C_7H_8O). It is not a true deodorant, but it masks offensive gases and vapours by its own strong and unpleasant odour. A 5 per cent. solution at least must be employed against resistant organisms. Many trade products, consisting of oils procured from the destructive distillation of coal, are on the market ("Izal," "Okol," etc.), and they for the most part possess disinfectant value similar to that of carbolic acid. They are dark brown liquids which, when added to water, form milky emulsions, one advantage in their use being that they are practically non-poisonous, and somewhat cheaper than pure carbolic acid. Among the emulsions containing cresols is "Jeyes' Disinfectant Fluid" and "Creolin." "Saprol" is a dark brown oily fluid, much used in Germany; it appears to be of similar strength to carbolic acid, and possesses the advantage that, while its contained phenols mix with liquids, an oily film floats over their surfaces.

Chloride of Lime ($CaCl_2O$, Bleaching-powder) is a mixture of chloride and hypochlorite of calcium, and contains about 35 per cent. of available chlorine. It gives off a most unpleasant odour. Chloride of lime solution is made by first stirring up the bleaching-powder with a little water so as to make a thick cream, and then diluting to the required extent. The solution exerts a corrosive action on metals, and it tends to dissolve the albumin of fæcal and other matter; its powers, however, may be entirely exhausted upon such

organic matter, and bacteria may by consequence escape. The disinfectant and deodorizing action of the solution is due to the fact that, in presence of moisture and carbonic or other acids, hypochlorous acid ($HClO$) is liberated, and this acts as an oxidizing agent by splitting up into HCl, and O. A 1·5 per cent. solution of the powder (about 2¼ ounces to the gallon), containing 0·5 per cent. of available chlorine, should generally be employed, except when dealing with organisms whose resistance is known to be slight; in such cases experiments show that a solution containing 1 part of chlorine in 1,000 will suffice.

Sodium Hypochlorite, like bleaching-powder, possesses considerable disinfecting power on account of its available chlorine. The strength at which it should be employed must be governed by the fact that the solution should contain in practice at least 0·5 per cent. of available chlorine, except where organisms of little resistance are to be dealt with. A liquid on the market, sold as "Chloros," contains 10 per cent. of available chlorine. Solutions of hypochlorites are apt to lose their strength somewhat on keeping; they should therefore be kept tightly stoppered in a dark place. The absence of lime renders a solution of sodium hypochlorite preferable to one of bleaching-powder, when the disinfectant is to be emptied down the drains.

Hypochlorous Acid is formed by the electrolysis of sea-water (Hermite process), which is thereby constituted a powerful deodorizing, but weak and unstable disinfectant solution.

Hydrochloric and other mineral acids are markedly disinfectant when employed in such strengths as will give the solution a marked acid reaction.

Iodine Trichloride (ICl_3) in solution is a more powerful

disinfectant than a hypochlorite, but the strength at which it may safely be employed has not yet been satisfactorily determined.

Sulphate of Copper ($CuSO_4$).—In 5 per cent. solution this salt is a powerful disinfectant, but little inferior to the perchloride of mercury. It acts by coagulating albumin and by exerting a poisonous action on bacteria. It will absorb ammonia, the compound ammonias, sulphuretted hydrogen, etc., and is therefore a useful deodorant.

Chloride of Zinc ($ZnCl_2$) is a poisonous salt with very similar properties to those of sulphate of copper. A 10 per cent. solution, to which a little hydrochloric acid has been added, should be employed where spores are concerned, but 5 per cent. will suffice for non-spore-bearing bacteria; it has, however, a corrosive action if used in solutions containing much more than 5 per cent. of the salt. Its disinfectant powers are somewhat inferior to those of sulphate of copper, but they are far superior to those of ferrous sulphate. "Burnett's Fluid" contains about 50 per cent. of $ZnCl_2$.

Ferrous Sulphate ($FeSO_47H_2O$, Green Copperas) acts mainly by its reducing action while taking up oxygen to become a ferric salt. It is a feeble disinfectant unless used in great strength (20 to 30 per cent.), but it is a good deodorant, absorbing ammonia and sulphuretted hydrogen. In practice it is suitable only for excreta, as it stains badly, and tends to form iron-moulds. The same general remarks apply to Fe_2Cl_6, which is, however, a feeble oxidizer.

"*Chinosol*" is a readily soluble crystalline yellow powder, with a slight aromatic odour, belonging to the quinoline group. Its solution is non-poisonous and non-corrosive, does not coagulate albumin, and possesses

marked deodorant properties. There is satisfactory experimental evidence to show that a 1 in 1,000 solution will rank with perchloride of mercury solution of similar strength.

Potassium Permanganate ($K_2Mn_2O_8$) is an oxidizing agent which can only be used in practice as a deodorant, since a 5 per cent. solution at least is required for the disinfection of resistant organisms. A solution of this strength would be expensive, and would stain everything with which it came in contact. Gases, like sulphuretted hydrogen, reducing salts in solution, and the more unstable organic matter, would first rob the permanganate of its oxygen; and the whole of the permanganic radical would probably have been reduced to black manganic oxide, or even to a lower oxide, before the bacteria were destroyed.

"Condy's Red Fluid" is a mixture of the permanganate and sulphate of potassium.

Formic Aldehyde (CHOH), in solutions of $\frac{1}{2}$ to 1 per cent., is a liquid giving off an irritating odour, and ranking high as a rapid disinfectant and deodorant; it costs far less than carbolic acid of equal disinfectant strength. An aldehyde is an alcohol *dehydrogenated;* thus, wood spirit (methyl alcohol, CH_3OH), when deprived of H_2, becomes CHOH, called formic aldehyde because it very readily changes to formic acid (CHOOH). In aqueous solution the gas can be concentrated to about 40 per cent., in which state it is sold as "Formalin."

Gaseous Disinfectants.

Formic aldehyde is also used as a gaseous disinfectant. The aldehyde vapours, which are non-poisonous, but very irritating to the eyes and throat, are powerful

disinfectants and deodorants. So far as their application for the purpose of the *surface* disinfection of rooms is concerned, they may be regarded as likely to fulfil all the requirements of everyday practice, if they are employed in sufficient quantities. Formic aldehyde is more rapidly disinfectant than equal quantities of sulphurous acid or chlorine, and it does not affect colours or (with the exception of iron or steel) metallic surfaces, although it fixes stains of blood or fæces. It is somewhat difficult to confine to the room, but there is no danger and little difficulty attending its practical application, if the rooms are well sealed up.

The production of the gas by means of specially devised methyl alcohol lamps is often imperfect and unsatisfactory in practice. In these the aldehyde is generated by allowing the vapour of wood alcohol, well mixed with air, to pass over the surface of red-hot platinum, when the alcohol is converted into aldehyde and water. The gas can best be liberated from formalin or formine (a purified 40 per cent. solution of the aldehyde) by means of Trillat's apparatus, in which the formalin is heated under pressure in an autoclave. A little calcium chloride is placed in the solution, which is then known as "formo-chlorol," and as the boiling-point of the calcium chloride solution is above 100° C., and the aldehyde is given off below that temperature, it may in this manner be obtained in a practically dry state. When the attached pressure-gauge registers a pressure of 40 pounds in the autoclave, the vapours are allowed to escape through a long thin copper tube, which is passed through the keyhole into the infected compartment. The apparatus costs about £18. Half an hour is required to get up the necessary pressure, and in an ordinary-sized room the vapours would be allowed to

escape for about half an hour. From $\frac{1}{2}$ to 1 litre of formochlorol should be employed for every 1,000 cubic feet, an extra quantity of the liquid being used in the autoclave to guard against danger from drying up. About twenty minutes is required to rid each litre of formochloral of its aldehyde.

This constitutes the best-known means of liberating large quantities of the aldehyde. Owing to the large quantities which can be generated and the high diffusibility of the gas, the method is specially suitable where passages, corridors, or staircases, with communicating rooms, require disinfection at the same time. The drawbacks against the adoption of the method by sanitary authorities are the weight of the apparatus and the time consumed in getting up steam and charging the room.

If an attempt is made to concentrate aqueous solutions of the aldehyde beyond 40 per cent. (formalin), polymerization ensues, and a precipitate of paraformaldehyde forms. This material is made into small tabloids, and sold as "Paraform Tabloids." A considerable amount of the aldehyde may be obtained, in a very convenient manner, by means of a spirit-lamp so constructed that the hot and moist products of combustion from the lamp act upon these paraform tabloids. The lamp sold for this purpose is known as the "Alformant" lamp; but the quantity of tabloids recommended by the vendors (*i.e.*, one to every 100 cubic feet of space) is from the writer's experiments too small always to insure disinfection. At least double the quantity should be employed.

The gas is neutralized by ammonia; and, if necessary, the last traces can be removed from a room by exposing vessels containing a little dilute solution of ammonia.

Goggles, specially made so as to protect the eyes, may be worn when the room is unsealed.

Sulphurous Acid (SO_2) is a gas with a density about double that of the atmosphere, and which therefore diffuses badly. It has a slight bleaching action, which is not sufficient, however, to militate against its use. In association with moisture it has marked disinfectant powers, a 5 per cent. solution killing the spores of *B. anthracis*, and a 1 per cent. solution killing non-spore-bearing bacteria, within twenty-four hours, according to Koch ; but unmixed with moisture it is little more than antiseptic. As against some adverse experimental data, the practical experience of many countries for generations as to its value must count for something ; and the fact that the method sometimes fails in practice, and that experimental evidence of its value is conflicting, may be more or less accounted for by the insufficient quantity of the gas generally employed. Like other acids, sulphurous acid absorbs ammonia, compound ammonias, and organic bases (ptomaïnes, etc.) ; it decomposes sulphides and sulphuretted hydrogen, and reduces or enters into combination with organic matter ; it also probably exerts a direct toxic effect on bacteria.

The whole process of disinfecting a room by sulphurous acid admits of division into two stages :

1. The charging of the atmosphere for from six to twenty-four hours with 2 per cent. of the gas. At least 2 per cent. should be employed, and even this may fail to destroy the more resistant organisms.

2. A subsequent thorough aeration of the room for several hours—an essential feature of this method.

The gas is generated and employed as follows :

1. Rolled sulphur is broken up into pieces of about the size of a marble, placed in an iron vessel, and then

moistened with a little spirit and ignited. At least 2 pounds of sulphur should be used for every 1,000 cubic feet of space, about 2 per cent. of sulphurous acid being thereby furnished to the atmosphere. The fact that the sulphur does not always burn out is a drawback to this method, and it is therefore preferable to employ—

2. Kingzett's sulphur candles, in which the powdered sulphur, mixed with inflammable material, is placed in a small metal saucer and lighted by a wick. These invariably burn out, and are very convenient and expeditious in use.

3. An ordinary benzoline lamp filled with carbon bisulphide; as this burns, sulphurous acid is given off ($CS_2 + 2O_2 = CO_2 + SO_2 + S$).

4. The gas can be liquefied by a pressure of three atmospheres (about 45 pounds to the square inch), the liquefied gas being passed into metal cylinders holding about 20 ounces. In use, a short piece of lead pipe with soldered end, which communicates with the interior, is cut off, and the cylinder placed in a basin with the cut surface downwards, when the liquid, being relieved of its pressure, passes into the gaseous state. At least two cylinders should be employed to every 1,000 cubic feet of space, for the contents of one cylinder would furnish slightly under 1 per cent. The cost of the cylinders is one shilling each.

Accidents by fire, when burning sulphur is used, have been very rare, but to guard against them it is well to support the burning sulphur over a pail or basin of water. This water, especially if hot, aids in saturating the atmosphere, and thereby increasing the disinfecting power of the gas, although probably the moisture already in the atmosphere is sufficient to fully hydrate the sulphurous acid produced. On account of the weight of

the gas, it should be liberated as high in the room as possible—*i.e.*, from the seat of a chair, which is placed on a table.

The gas is so irrespirable that it is often impossible to enter and unseal the room containing it. A wet towel, moistened with washing soda, and placed over the mouth, will always enable the operator to enter. As bronze, gilt, and copper surfaces are tarnished by the sulphur fumes, these should, where detachable, be wiped with 1 per cent. carbolic and placed just outside the room, prior to the liberation of the sulphurous acid.

Disinfection by this gas is the official method of room disinfection in this country, the United States, Austria, Belgium, Holland, Sweden, etc.

Chlorine (Cl).—This gas has most of the defects of sulphurous acid; it is a very irritant and heavy gas, which diffuses badly, and moisture is essential to its disinfectant action. Compared with sulphurous acid, it is a heavier gas, possessing greater bleaching properties, and somewhat more irritant; it is less convenient in use and more expensive. On the other hand, when present to the extent of 1 per cent. in the atmosphere, its disinfectant power exceeds that of a similar strength of sulphurous acid.

The disinfectant and deodorant properties of the gas depend upon its affinity for hydrogen. Thus, in the presence of moisture, and especially in daylight, it releases nascent oxygen ($Cl_2 + H_2O = 2HCl + O$), which burns up organic matter, including of course bacteria. It decomposes sulphuretted hydrogen

$$(Cl_2 + SH_2 = 2HCl + S),$$

and also ammonia

$$(3Cl_2 + 8NH_3 = 6NH_4Cl + N_2).$$

It is usually produced by the action of sulphuric or hydrochloric acid on bleaching-powder

$$(CaCl_2O + 2HCl = CaCl_2 + H_2O + Cl_2).$$

It is advisable to use 2 pounds of bleaching-powder and about 1 pound of the commercial acid for every 1,000 cubic feet of space; and the mixture should be divided into several parts, because of its bulk and to ensure distribution of the gas, and placed as high in the room as practicable. Some experiments indicate the necessity of using much larger quantities of the bleaching-powder for the more resistant infections. The powder contains about 35 per cent. of available chlorine, and it must be kept dry.

All metal fittings and articles of silk, etc., should be removed beforehand; and if great difficulty is experienced in entering the room for the purpose of unsealing, the operator should first saturate a towel with weak ammonia solution and place it over his mouth.

Bromine (Br) is a heavy gas, more irritating than chlorine, more destructive to articles exposed to it, and also more expensive. It is readily given off from the volatile fluid known as "liquid bromine." As with chlorine, the presence of moisture is essential to the disinfecting action of the gas, which is inferior to that of chlorine and somewhat superior to that of iodine.

Iodine (I) is a heavy gas some eight times heavier than air, and more than three times as heavy as chlorine. This circumstance, added to the fact that it stains exposed articles and is not a powerful germicide, excludes iodine from the list of serviceable gaseous disinfectants.

Hydrochloric Acid (HCl) fumigation has been advocated. Like other acids, it has marked disinfectant properties, which are doubtless mainly due to the cir-

cumstance that any marked acidity is inimical to germ life.

Nitrous Acid (HNO_2).—Nitrous acid acts as an oxidizer owing to the circumstance that it readily parts with oxygen to oxidizable matter and becomes nitric oxide (NO). This gas combines with the oxygen in the atmosphere ($2NO + O_2 = 2NO_2$), and thus serves as a carrier of oxygen to oxidizable matter. Nitrous acid, therefore, remains constantly active, and is not used up like chlorine, over which it also possesses the additional advantage that it does not destroy organic colouring matters. The reddish fumes of nitric peroxide (NO_2) are very irritating, and their disinfecting powers are inferior to those of chlorine, For every 1,000 cubic feet of space at least 3 ounces of nitric acid should be mixed with an equal volume of water, and the mixture poured upon 1 ounce of copper shavings placed in an old jar or basin—

$$3Cu + 8HNO_3 = 3Cu(NO_3)_2 + 2NO + 4H_2O.$$

Vaporized Phenol (C_6H_6O).—Although it is claimed by some that the use of this agent succeeds well in practice, such large quantities have to be employed that the odour which remains after use is extremely persistent. The phenol, placed in a bottle-shaped metal receiver, may be vaporized by means of a small rod made red-hot, which is placed inside the receiver and allowed to remain there. A pint of phenol can be vaporized in this way. Cresol diffuses better than carbolic acid or "Izal."

Solid Disinfectants.

These can only be conveniently and effectually employed as deodorants in the form of powders.

Powders are made containing phenols, sulphurous acid, etc., but they all lose strength on keeping.

Carbolic Powders.—The "vehicle" for the carbolic acid is frequently lime, which is often in very great excess. There is a resulting formation of carbolate of lime, and the powder soon becomes practically inert, for the reason that it contains little or no available carbolic acid. The best class of carbolic powders are warranted to contain at least 15 per cent. of phenols, silicious matter not lime being used as their basis ("carbolized silicate powders"), or absorbent wood fibre, or peat ("carbolized peat-powders"). All such powders are liable to lose from 1 to 2 per cent. of carbolic acid by volatilization.

Slaked Lime is a good deodorant, as it absorbs sulphuretted hydrogen and most organic vapours. Like *bleaching-powder*, it exerts a caustic action, and attacks metals. Bleaching-powder (chloride of lime) deposits about 40 per cent. of lime, and should not, therefore, be put down drains.

A mixture of equal parts of "Sanitas Powder" and lime is a good deodorant, which of itself gives off no unpleasant odour.

Carbon condenses gases in its pores, and oxidizes them by means of the condensed oxygen therein contained. Vegetable charcoal is a better deodorant than animal, but both forms should be only employed when freshly prepared and dry.

Ordinary *Soap* possesses marked disinfecting properties. There is little or no advantage in using soaps impregnated with small quantities of disinfectants.

Room Disinfection.

Wearing apparel and bedding should be steam-disinfected; and if carpets, curtains, rugs, and upholstered articles were not removed when the sick-room was prepared for the patient, these should also be set aside for

steam disinfection. The disinfection of the room is practically one of surface disinfection only. Judged from the standpoint of its power of penetration, no known means of room disinfection is satisfactory, whether the agent employed be used as a spray, a gas, or a vapour; for no gas or vapour, employed at the current temperature and pressure, possesses powers of penetration to any valuable degree.

To be satisfactory in practice, a method of room disinfection must be efficient for its purpose, but must not injure the articles exposed. The facility of application and the cost are also important considerations.

There are three well-known methods, involving:

1. The use of what have been termed "aerial disinfectants," in which the air is charged with the disinfectant in the form of a gas or vapour, for a period of from six to twenty-four hours. In this method the room should be, as far as possible, hermetically sealed—the windows closed and chinks pasted over with paper, the chimney outlet closed up, and the door crevices and keyhole carefully pasted over. Before the room is again occupied, the wall-papers should be stripped and the ceiling lime-whited.

2. The use of sprays or atomizers, by which the disinfectant in solution can be applied directly in the form of a very fine spray to the surfaces of the room.

3. The washing of all surfaces with a solution of the disinfectant, or the rubbing down of such surfaces with breadcrumbs.

In the case of schools and hospitals, the skirting and floor-boards should be removed and washed, and all ventilators should be swept out and disinfected.

After the room has been dealt with, the bedding, clothes, etc., should be placed within fine canvas bags,

which should be damped outside with water, and then taken to the van for removal to the disinfecting-station for steam disinfection. The moistening of the bag is a precaution against the dislodgment and escape of bacteria from it during the removal of the articles from the room, through the house, and to the station.

As mistakes sometimes happen, it is necessary to make out a list of the articles removed from each house, and to obtain the signature of some responsible person to this list. The use of canvas bags, which can be placed with their contents direct into the stove, reduces the possibility of the mixing of articles from different houses, and obviates the necessity of the man at the station handling the infected articles. Any articles, however, which are stained, and require to have the stains removed before being placed in the stove, would be overlooked unless a special bundle is made of them.

The individual engaged in preparing a room for disinfection should always wear overalls, which should be afterwards left behind in the room, and removed with the other articles for steam disinfection. This precaution diminishes the risk of the infection being conveyed from the sick-room, and when the disinfection is performed by the sanitary authority the precaution serves as a useful object-lesson to the people.

A great deal has been claimed for the spray method of disinfection in France, where it is the official one.

The efficiency of a good sprayer must depend on its ability to deliver the liquid in the most finely-divided state possible, for the more this requirement is met, the more uniform will be the distribution of the disinfectant. The Equifex sprayer consists of a metal reservoir, which holds the disinfectant, and is lined with ebonite, so that the metal is not attacked. The fluid is driven through a

spray nozzle by means of a hand-pump, which forces air into the reservoir. An extremely fine spray, at a velocity sufficient to insure a slight degree of penetration, is made to issue from the end of a metal tube of such a length that it can be held close to all the surfaces to be treated. The cost is from £8 to £16.

The disinfectant solutions to be preferred in spraying are: Perchloride of mercury, formic aldehyde, "Chinosol," or sodium hypochlorite. The operation of disinfecting a small room occupies one hour.

Washing and Rubbing Methods.—All the horizontal surfaces of a room may be washed down, or coated with disinfectant by means of a large paint-brush, and the vertical surfaces may be wiped and stroked with a rag moistened with the disinfectant. When a brush is employed, two coats of the disinfectant should be put on, one with vertical strokes and the other with horizontal, to insure that the disinfectant reaches all the crevices. The German official method is to rub down the walls with bread—ordinary German loaves, forty-eight hours old, being employed, cut into pieces 6 inches square, with the crust at the back to afford a firm hold. The crumbs having been swept up and burned, the walls and ceilings are thoroughly sprinkled with carbolic solution, and the floors and furniture are washed with this solution.

An advantage which is claimed for gaseous disinfectants is that their use necessitates, before the room can be reoccupied, a thorough exposure to fresh air for several hours—itself a useful adjunct to disinfection.

While the room is occupied by an infectious patient, it is a very general custom to hang a sheet outside the door, and to keep this sheet constantly moistened with disinfectant. There is a tendency to regard the practice

as useless, but its retention is certainly to be advocated. Although such a sheet cannot present an impassable barrier to the passage of infection, it must tend to limit the infection; and its presence serves as a warning to all, and an object-lesson of the constant necessity for precaution.

Books.—Books liable to injury by being placed in a hot-air stove may be disinfected in a small compartment in which formic aldehyde vapours, in sufficient quantity to furnish 2 per cent. to the atmosphere, are generated. The compartment is then sealed for two to four hours. In the ceiling of the compartment several lines of wire are loosely fixed, so that the books can be suspended by their covers, the pages being open, fan-shape, to admit the disinfectant.

Dead Bodies should be wrapped in a sheet soaked in "Izal," carbolic acid (5 per cent.), perchloride of mercury (1 in 500), formic aldehyde (1 per cent.), or other disinfectants of equal strength. Cremation is specially desirable in the case of infectious bodies.

Gullies may be sprinkled over with a good carbolic powder, or with a mixture of equal parts of "Sanitas Powder" and lime. Bleaching-powder has too unpleasant an odour, and it badly corrodes the metal grids.

Stools, etc.—To disinfect enteric fever stools, cholera evacuations, tubercular sputa, and other discharges from the infectious sick, either liquid disinfectants or cremation must be employed. The following liquid disinfectants may be employed: Acid solution of corrosive sublimate (1 in 1,000) coloured blue with aniline. Preparations containing carbolic or cresylic acid (5 per cent.), or two tablespoonfuls of the acids to 1 pint of water. Solution of sulphate of copper or ferrous sulphate (5 per

cent.). Solution of formic aldehyde (1 per cent.). Bleaching-powder solution, acidified (2 per cent.). All solid stools should be broken up with a piece of stick and thoroughly mixed with the disinfectant. The agent must be allowed to remain in contact with the infected material for at least half an hour; and all disinfectant solutions must be added to the matter to be disinfected in such quantities that they are *present in the whole mixture* to the required extent, as indicated above.

The impossibility of disinfecting or sterilizing large volumes of sewage or night-soil by the use of chemical reagents, unless applied in enormous and ruinous quantities, need hardly be insisted on. Small quantities of chemical reagents may be very efficient deodorizers, for offensive smells are easily concealed or destroyed; and by the ignorant the removal of offensiveness is regarded as equivalent to destruction of infection.

The Disposal of the Dead.

Cremation is the most sanitary method of disposal of the dead. The method is of great antiquity, and was commonly employed by the ancient Greeks and Romans. The body can by this method be reduced, within the space of one hour, to a small quantity of odourless ash, which can, if the relatives of the deceased so desire, be preserved in sealed urns. Compared with earth-burial and the slow putrefactive changes which ensue in earth, the process of resolution of the body into its component elements by cremation is one of extreme rapidity. Cremation, too, prevents the pollution of the ground—a pollution which is of a highly dangerous character, where the bodies of those who have died of infectious diseases are interred.

The main objections which are raised against cremation at the present day are based on sentimental and religious grounds, which time and education will remove, for the ultimate effects of cremation and earth-burial are precisely the same. In earth-burial the ultimate resolution of the body into its component elements may take a year or many years to accomplish, whereas by incineration the same products are formed in as many hours. These products are largely gaseous, and whereas in cremation special provision is made to completely burn them up without offence, in earth-burial they necessarily pollute the soil, and escape into the general atmosphere. There are only two real objections which can be raised against cremation: namely, the cost of the process, and the fact that the complete destruction of the body involves also the destruction of any evidence of crime, where the body is that of a person who has been poisoned. As regards the first objection, the original cost of erection of a crematorium is considerable, and the working expenses are high; but, where there is a crematorium within easy access by road or rail, cremation can now be carried out at about the same cost as earth-burial. To meet the second objection, State officials could be appointed, as in France and Germany, to inquire into and verify the death certificates; and, as a means to the same end, the English Cremation Society has drawn up a code of very stringent rules which must be complied with before a body can be cremated. By the use of quicklime in earth-burial the soft tissues of the body are rapidly destroyed, and the process of decomposition is completed at a comparatively early period.

Earth-burial.—This method causes pollution of both soil and air, and should be discontinued within the borders or in the near neighbourhood of towns and

thickly populated districts. In some cemeteries very serious scandals have arisen from the practice of interring too many bodies in a single grave, and subsequently re-opening the ground and breaking open the coffins, in order to make room for fresh interments. As the old burial-grounds in towns become filled up they have to be closed, and can then be converted into open spaces and garden recreation-grounds. Burial sites at a distance from the town must then be provided at a large cost and much inconvenience to the ratepayers.

It is necessary, in order to carry out earth-burial under the most favourable conditions, to provide from a quarter to half an acre of land to every 1,000 of the population, according to the suitability of the soil for the purposes of interment.

A sandy and calcareous loam is the best soil for a graveyard; a stiff clay, which retards dissolution, is the worst. In clay sites, moreover, the ground is liable to crack in very dry weather, and the gases of putrefaction may then find a direct outlet to the surface of the burial-ground. Coarse gravel, comparatively free from any binding material, and broken rock are too loose and open to constitute good soils for burial sites; and chalk is contra-indicated on account of the risk of fissures transmitting impurities to the air above or to a water-supply below. An isolated tract of ground, with good surface falls for natural drainage, and having a considerable thickness of fine sand and sandy loam, or sandy and loamy gravel, resting upon a deep bed of clay, would constitute an ideal site. The earth should have a depth of not less than 10 feet, and graves should never be dug deeper than 8 feet from the surface. In every case a space of at least 2 feet should intervene between the bottom of the grave and the surface of the subsoil water.

As at present practised, with the use of lead shells and strong wood coffins, the method of earth-burial has for its object the preservation of the bodies for a very long period. Nothing whatever is gained by this lengthy preservation; and the aim of rational earth-burial should be to facilitate the ultimate reduction of the body into its component elements. To this end, the body should be placed in an easily perishable coffin of wickerwork or of unprepared wood, and the grave should not be deeper than from 3 to 5 feet from the surface—the earth being very much more active as a purifying agent in the upper layers not exceeding 5 feet in depth from the surface, than it is at greater depths.

Other methods of disposing of the dead are: (1) By simple exposure to the air, as practised by the Australian aborigines; (2) committal to the sea; (3) the exposure of the body in the open air, so that the fleshy parts may be eaten by vultures, a method followed by the Parsees of India in their Towers of Silence; (4) desiccation or mummification.

Embalming was commonly practised in ancient Egypt. The abdominal viscera were extracted by incision on the left side, and the cavity was then cleansed with palm-oil and filled with myrrh, cassia, and other odoriferous substances. The body was ultimately wrapped in very numerous layers of cloth and sealed up hermetically. In the modern method of temporarily preserving bodies, the cavities of the chest and the abdomen are emptied and washed with camphorated spirit; the organs are then similarly washed and injected with some preservative fluid before they are replaced. The vascular system is also injected with a preservative fluid, it being a common practice to inject into the carotid artery some 6 to 8 pints of a mixture consisting of carbolic acid

1 part, glycerine 10 parts, alcohol 50 parts, and water 40 parts. The surface of the body should be lubricated with vaseline containing 1 per cent. of carbolic acid, and it is advisable to fill the cavities of the body with cotton wool soaked in glycerine containing 5 per cent. of carbolic acid.

CHAPTER XI.

STATISTICS.

Statistical Inquiries.

The science of statistics consists in the collection of individual facts, with the view of grouping them into different classes according to certain definite characters they possess. The rule to which attention must be specially directed in differentiating a series of facts, is that the points of difference or characteristics on which a group is to be formed should be common to each member of that group, but absent from the members of all other groups. The dividing character must be constant, and must be definite.

It does not follow that, because in any series of cases the groups bear a certain numerical proportion to the total number of cases, these proportions will be the same in any subsequent series of like cases, unless the numbers dealt with in the first case are infinitely large.

The relative values of two or more series are as the square roots of the number of units of observations; and thus by increasing the number of observations in any inquiry, the value (or accuracy) increases as the square root of the number.

The smaller the number of individual facts on which the groups are founded, the greater is the possible devia-

tion from the proportions which may be observed in any subsequent series of like facts. By *Poisson's Rule* the limits of error, or the degree of approximation to the truth of the numerical relations existing between the units or groups of units of a series, may be ascertained.

Let M = total number of cases in the series recorded.
,, m = number of cases in one group.
,, n = number of cases in the other group.

Then $m + n = M$, and $\frac{m}{M}$ and $\frac{n}{M}$ are the proportions of each group to the whole. But on subsequent occasions, with another series of like cases, the proportions may be

$$\frac{m}{M} + 2\sqrt{\frac{2.m.n}{M^3}}\ ;\ \text{or}\ \frac{m}{M} - 2\sqrt{\frac{2.m.n}{M^3}}.$$

And the same holds good with n group of cases. The larger the value of M, the less will be the value of the fraction of which M^3 is the denominator, and consequently the smaller the error to be added to or subtracted from $\frac{m}{M}$ or $\frac{n}{M}$.

Example.—

$M = 100$ cases of fever.
$m = 25$ cases which die.
$n = 75$ cases which recover.

Then the proportion $\frac{m}{M}$ or $\frac{1}{4}$ may be in other instances

$$\tfrac{1}{4} + 2\sqrt{\frac{2 \times 25 \times 75}{100^3}} = 0{\cdot}25 + 0{\cdot}1225 = 0{\cdot}3725\ ;$$

$$\text{or}\ \tfrac{1}{4} - 2\sqrt{\frac{2 \times 25 \times 75}{100^3}} = 0{\cdot}1275.$$

That is to say, the number of deaths out of 100 other cases of the same fever, instead of being 25, may be as many as 37, or as few as 13. But if, instead of 100 cases of fever in the original series, there had been 10,000 cases, the limit of error would have been only 1·225 per

cent. above or below the proportion found actually to exist.

The arithmetical mean of a series of figures is obtained by adding together the numerical values of the figures, and dividing the total by the number in the series. This mean number will have a higher numerical value than belongs to some of the figures composing the series, and a lower numerical value than belongs to others. The less the difference between the mean and the figures of the series, the greater is its value, and the more closely does it conform to a true average. The relative values of two or more similar series are as the reciprocals of the squares of the probable errors; that is as $\frac{1}{(pe)^2}$, where *pe* is the probable error. The probable error is approximately two-thirds of the mean error, and implies that, if the series were prolonged indefinitely, the error would probably as often exceed as fall short of this mean. It is obtained as follows: 1. Find the *mean* of the series of observations; find the *mean* of all the observations *above* the mean, and subtract the mean from it; this gives the mean error in excess. 2. Find the *mean* of all the observations *below* the mean, and subtract the latter from this mean; this gives the mean error in deficiency. Add the two quantities (mean error in excess and mean error in deficiency), and take the half; this is the *mean error.*

The various "means" are:

The arithmetical mean $= \dfrac{a+b+c+d+e}{5}$

The geometrical mean $= \sqrt[5]{a\ b\ c\ d\ e}$

The harmonic mean $= \dfrac{5}{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d}+\frac{1}{e}}$

The quadratic mean $= \sqrt{\dfrac{a^2+b^2+c^2+d^2+e^2}{5}}$

If the terms of the series are equal, the above means are all identical. If the terms are unequal, the quadratic mean is the highest, the arithmetical comes next, and then follow the geometrical and harmonic means.

Vital Statistics.

The uses of vital statistics are to obtain information as to the health of the people and the various diseases from which they suffer; to assist in the study of the good and evil conditions affecting them; and to furnish the necessary data for life assurance.

To obtain the statistics of a community which have relation to its public health, it is necessary to have a correct enumeration of the population, a complete registration of births and deaths, and, in the case of deaths, a correct statement as to their cause, together with the age of every deceased person. The number of births and deaths which take place in the course of a year are generally expressed in the form of rates, *i.e.*, so many births or so many deaths to 1,000 of the population.

The first inquiry, therefore, which becomes necessary is to ascertain for any community the number of the living during any year, or at any period of a year. The last census returns give the exact enumeration of the numbers living and their ages at the time the census was taken. If the population is stationary—the births equalling the deaths and no emigration or immigration taking place—the census returns are true for any subsequent year. In this country the births have, for a great number of years, exceeded the deaths and the emigrations, with the result of a steady increase of the population.

By the *Law of Population*, a population increases in regular geometrical progression when the births exceed

the deaths and the ratio of the births and of the deaths to the population remains constant.

Example.—If the birth-rate of a population numbering 5,000 is 30 per 1,000, and the death-rate is 20 per 1,000, and these rates remain constant for ten years, the annual rate of increase is 10 per 1,000, or 0·01 per unit; *i.e.*, one person becomes 1·01 at the end of the year, or 1,000 persons become 1,010. The population at the end of the tenth year (the last term of the series in geometrical progression) $=5{,}000 \times 1{\cdot}01^{10}=5{,}523$ persons. For the population at the end of the first year is $5{,}000 \times 1{\cdot}01$; at the end of the second year it is $(5{,}000 \times 1{\cdot}01) \times 1{\cdot}01=5{,}000 \times 1{\cdot}01^2$; at the end of the third year it is $(5{,}000 \times 1{\cdot}01^2) \times 1{\cdot}01=5{,}000 \times 1{\cdot}01^3$; and at the end of the tenth year it is $5{,}000 \times 1{\cdot}01^{10}$.

The term "increment of life" is sometimes employed to denote the excess of births over deaths in a population, and if the balance is on the opposite side it is sometimes referred to as the "decrement of life."

Sometimes the terms "effective" and "specific" are applied to a population. The "effective" population is the population between the ages of twenty and seventy, and the "specific" population is the number of persons to each acre or square mile, which is the same thing as the density of the population.

In calculating birth-rates or death-rates for any year, the estimated population for the middle of that year must be taken as the basis; for it alone represents the average number of persons who are living throughout that year. The following method is used by the Registrar-General for estimating the population of a town or district for the middle of any year from the last two census returns.

Example.—Suppose the population of a town by the census of 1881 is x, and by the census of 1891 is y, and it is required to know the population in the middle of the year 1895. Then the log. y − log. x = log. of the rate of increase for 10 years. This divided by 10 will give the log. of the rate of increase for 1 year. From the end of the first quarter of 1891 (when the census was taken) to

the middle of 1895 is $4\frac{1}{4}$ years, and therefore the log. of the population in the middle of $1895 = \log. y + (4\frac{1}{4} \times \log.$ of 1 year's increase). The number corresponding to this logarithm will give the calculated population.

This method assumes that the population of the town is increasing or decreasing in the same ratio since the last census as it did between 1881 and 1891. It is here that a fallacy may arise. The population which serves as the basis for calculating the birth and death rates in the ten years intervening between any two census returns is only an estimate, and therefore only approximately true. The estimates of population so obtained generally exhibit a considerable divergence from the actual truth in the years most remote from the last census. Consequently, statistics calculated upon such estimates are usually erroneous. A comparison may be made between this estimate and that arrived at by a calculation of the number of inhabited houses in the district, as obtained from the rate-books, and the average number of inhabitants in each, as shown by the last census; but this, again, is only an approximation. The average number of persons per house may vary from 4·5 to 9, according to the size of the house and the class of property. One individual should be allowed to each empty house, in order to account for caretakers and their families. Another means of checking the estimated population is by the birth-rate, if this remains fairly constant in a series of years; and this computation is found to hold good when applied to large populations. Then the population

$$= \frac{\text{registered births in the year} \times 1{,}000}{\text{average birth-rate for previous 10 years}}.$$

It is, however, most desirable that the census should now be quinquennial instead of decennial.

Birth-rates and death-rates may be calculated as

annual rates to 1,000 persons living from weekly, monthly, or quarterly returns. When the returns are for a less period than a year, the rate represents the number of births or deaths that would take place per 1,000 of the population in a year, if the proportion of births or deaths to population recorded in these shorter periods were maintained throughout the year. Now, the correct number of days in a natural year is 365·24226, and the correct number of weeks is 52·17747. The birth-rate or death-rate may be accurately calculated from weekly, monthly and quarterly returns as follows:

A weekly death-rate =

$$\frac{\text{number of deaths recorded in week} \times 52{\cdot}17747 \times 1{,}000}{\text{the population}};$$

a monthly death-rate =

$$\frac{\text{number of deaths recorded in four weeks} \times 13 \times 1{,}000}{\text{the population}};$$

a quarterly death-rate should deal with the thirteen weeks which most nearly correspond to the natural quarter, and =

$$\frac{\text{number of deaths recorded in quarter} \times 4 \times 1{,}000}{\text{the population}}.$$

In large towns a certain number of deaths occur in public institutions (hospitals, workhouses, etc.), which have to be allotted to the districts in which the deceased persons resided. In London, for instance, which is divided into a number of boroughs, in calculating the death-rate of any borough, the deaths of non-parishioners which occur in public institutions in the borough must be excluded; whilst deaths of parishioners occurring in the public institutions in the borough and outside it must be included in order to arrive at the true death-rate. In London, the figures required for this purpose are now

supplied to Medical Officers of Health from the Registrar-General's office. Formerly it was the custom to assign to each parish, out of the total deaths in public institutions in London, a number proportional to its population.

The higher birth-rate in large urban districts is due to the following causes: The greater proportion of women at child-bearing ages, the higher marriage-rate, the earlier marriages, and the greater infantile mortality. The state of national prosperity to a large extent determines the birth and marriage rates.

The marriage-rate is usually expressed as

$$\frac{\text{number of marriages} \times 1{,}000}{\text{population}};$$

but it should more properly be expressed as the number of persons married annually per 1,000 marriageable persons—*i.e.*, those over fifteen years who are unmarried.

The marriage-rate is highest in large towns to which many young adults emigrate from country districts, and where more constant labour at a higher rate of remuneration than in the country can be secured. The average annual fecundity of married women of reproductive ages is about 260 live births to 1,000 women.

It may be well to point out in this place—especially as misunderstanding is constantly arising on the subject —what is the true significance of death-rates, and how far they are reliable as tests of the health and sanitary surroundings of different communities.

Death-rates constructed from the mortality returns of short periods, such as a week or month, are not reliable as tests of health. They are necessarily subject to accidental fluctuations, which must prevent any true conclusions being drawn from them. So, too, with the death-rates of very small populations, even when they

exhibit returns covering a period of a year. The numbers on which the figures are founded are not sufficiently large to exclude those accidental fluctuations from varying circumstances which must be got rid of before any just reasoning can be founded on death-rates. It is different with the death-rates from yearly returns of larger populations. Where the units on which the figures are founded are sufficiently large, accidental fluctuations are submerged, so to speak; and the errors traceable to them are reduced to such small limits that trustworthy conclusions can be drawn.

But, in comparing death-rates of different towns or districts with each other, there are other sources of error which must be taken into account. A population consists of a number of people living at every age, from the time of birth to one hundred years or more. Now, the age-distribution of two or more populations may vary widely, the proportions of children, adults, and old people to the total population in different cases being often very different. If the death-rate were the same for all ages, this different age-distribution might be neglected. But such is not the case; children under five and old people over fifty-five years of age die at a greater rate; whilst those from the age of five up to fifty-five die at a less rate than that represented by the general rate. There is another disturbing factor, and that is the proportionate number of males to females in any population. Females at all ages have lower death-rates than males, except in the age-period ten to twenty, when the female rate is slightly higher. The causes of the higher male mortality are chiefly to be found in their more exacting and dangerous occupations and their greater indulgence in alcohol.

The following table exhibits the death-rates at different

age-periods (calculated upon the numbers living at each age-period) amongst males and females in England and Wales during the ten years 1881-90.

	Males.	Females.
All ages	20·2	18·0
Under 5 years	61·7	52·0
5-10 ,, ...	5·3	5·2
10-15 ,, ...	2·9	3·1
15-20 ,, ...	4·3	4·4
20-25 ,, ...	5·7	5·5
25-35 ,, ...	7·7	7·3
35-45 ,, ...	12·3	10·5
45-55 ,, ...	19·3	15·0
55-65 ,, ...	34·7	28·4
65-75 ,, ...	70·2	60·1
75 and upwards	160·2	147·3

(Supplement to the 55th Annual Report of the Registrar-General.)

From these figures, it will be seen that it would not be right to compare the general death-rates of two towns, one of which, let us suppose, had a larger proportion of females and of young adults, and a smaller proportion of males and old people, than the other. Corrections must therefore be made for differences in the age and sex distribution. It is for this reason that the uncorrected death-rates of rural districts overstate, whilst the death-rates of large cities understate, the real mortality. In many parts of large towns the density of population is very great—200 persons to an acre or more—and the death-rate correspondingly high. The high death-rates which go with dense population are not simply the result of aggregation. Aggregation means, no doubt, generally polluted air and possibly polluted water and soil, and the easy spread of infectious disease. But, as Dr. Ogle has pointed out, the more crowded a community, the

greater the amount of abject want, filth, crime, drunkenness, and other excesses, the more keen is the competition, and the more feverish and exhausting the conditions of life. It is, too, in these crowded communities that the most dangerous and unhealthy industries are carried on. These indirect consequences of aggregation influence the mortality greatly more than the direct.

Besides normal increase of population by excess of births over deaths, the immigration into large towns, which always greatly exceeds the emigration from them, tends to bring large numbers of young adults into the population, and so influences the age-distribution.

The following table gives the age-distribution of 1,000 persons in England and Wales (mean of censuses of 1881 and 1891):

All ages.	Under 5.	5-10	10-15	15-20	20-25	25-35	35-45	45-55	55-65	65-75	75 and upwards
1,000	129	119	110	100	90	149	114	85	58	33	13

The Registrar-General has adopted the following method for making the necessary corrections for age and sex distribution in any population (Annual Summary, 1883):

The standard death-rate of the population is first obtained. This is a death-rate calculated on the hypothesis that the mortality of the population at each age-period and for each sex corresponds to that obtaining in England and Wales as a whole. The facts as to the age and sex distribution of the population of any area are ascertained from the last census returns, and thus the

population can be split up into the numbers living of both sexes at the different age-periods. Then, for the purpose of calculating the standard death-rate of the district, it is assumed that those living in each of the groups will die at the same rate as those die in the similar age-periods in England and Wales generally; and thus a hypothetical number of deaths is arrived at, on the basis of applying the death-rates of England and Wales at different age-periods to those living at such age-periods in the particular population under consideration. The total deaths thus calculated × 1,000, and divided by the population under consideration, will furnish the standard death-rate. Now, it is obvious that if any town has the same relative proportions of males and females in the different age-periods as England and Wales, then, if the mortality-rates of England and Wales for each of these age-periods and for both sexes are applied to these numbers, the standard death-rate of that town will be the same as the death-rate of England and Wales. Any difference, therefore, can only be due to the fact that the town population has a different age and sex distribution.

The death-rate of England and Wales is therefore divided by the calculated standard death-rate; and thus a factor is obtained which, when multiplied into the recorded death-rate, serves to make allowance for differences of age and sex distribution, and to furnish a corrected death-rate—comparable with that of England and Wales and of other towns corrected on the same basis. As an example of the method of arriving at a corrected death-rate, the following may be given (Newsholme's "Vital Statistics"):

Ages.	Mean Annual Death-rate of England and Wales, 1881-90, per 1,000 living at each Group of Ages.		Population of Huddersfield in 1891.		Calculated Number of Deaths in Huddersfield.	
	Males.	Females.	Males.	Females.	Males.	Females.
Under 5	61·59	51·95	4,551	4,785	280	249
5-	5·35	5·27	4,691	5,081	25	27
10-	2·96	3·11	5,113	5,165	15	16
15-	4·33	4·42	4,905	5,549	21	25
20-	5·73	5·54	4,541	5,461	26	30
25-	7·78	7·41	7,466	8,834	58	65
35-	12·41	10·61	5,576	6,265	69	66
45-	19·36	15·09	3,944	4,649	76	70
55-	34·69	28·45	2,393	3,017	83	86
65-	70·39	60·36	1,128	1,590	79	96
75 and upwards	162·62	147·98	250	466	41	69
Totals ..			$\underbrace{44{,}558 \quad 50{,}862}_{95{,}420}$		$\underbrace{773 \quad 799}_{1{,}572}$	

The standard death-rate for Huddersfield is therefore $\frac{1{,}572 \times 1{,}000}{95{,}420} = 16{\cdot}47$ per 1,000. The annual death-rate of England and Wales in 1881-90 was 19·15. The factor for correction for Huddersfield is, therefore,

$$\frac{19{\cdot}15}{16{\cdot}47} = 1{\cdot}1627.$$

The age and sex distribution of Huddersfield is thus seen to be more favourable to a low death-rate than that for the country as a whole; and when the recorded death-rate is multiplied by the factor and brought into comparison with the death-rate of England and Wales, it is thereby increased. As a general rule, in rural districts the age and sex distribution of the population is less favourable to a low crude death-rate than that in urban districts (Newsholme).

The comparative mortality figure is a useful means of

expressing a comparison of the mortalities in different districts. For any year it is—

$$\frac{\text{the corrected death-rate} \times 1{,}000}{\text{death-rate of England and Wales}}.$$

Taking Huddersfield again as an example, the comparative mortality figure of that town for 1897 =

$$\frac{19{\cdot}07 \times 1{,}000}{17{\cdot}43} = 1{,}094.$$

This implies that, after making allowance for age and sex distribution of the population, the number of living persons that in England and Wales in 1897 furnished 1,000 deaths, in Huddersfield actually furnished 1,094.

The factor for correction exceeds unity in twenty-six out of the twenty-eight large towns of the Registrar-General, thus showing that their death-rates without correction are understated, and is less than unity in the remaining two towns, in these two cases the uncorrected death-rates being overstated, when compared with the country generally.

The death-rate from a disease affecting only a particular class should be expressed as the number of these deaths to every 1,000 of those who are liable to contract the disease. The death-rate from puerperal fever, for instance, should be taken as

$$\frac{\text{the deaths from puerperal fever} \times 1{,}000}{\text{the number of registered births}},$$

since it is only those females who have recently been delivered of a child who are liable to die from this complaint.

The general death-rate fluctuates considerably throughout the year. In large communities it is generally high through January, February, and March, and falls con-

siderably through April, May, and June. It often rises again through July and August, to fall in September and October, and it again rises in November and December.

Mild winters and cool summers favour a low death-rate, from the lessened mortality from respiratory diseases and intestinal diseases respectively. Density of population, on account of the co-existent poverty, has a great effect in swelling the mortality of a district.

In determining the cause of death or the origin of an outbreak of disease, much more than the mere concurrence of two phenomena is required to prove their relation as cause and effect. The inductive methods of agreement, of difference, and of concomitant variations must be worked through, and the possibility of a plurality of causes should never be lost sight of.

We are now in a position to understand the influence of birth-rate upon death-rate. In large towns high death-rates go with high birth-rates; but, as pointed out by the late Dr. Farr, high death-rates are not the result of high birth-rates; they are more generally caused by density of population (overcrowding on space and in houses) and by bad sanitary conditions. High birth-rates should cause a lowered death-rate; for if year by year the births exceed the deaths amongst a population, not only are additional children under five years of age, whose mortality is high, added to the population, but a still larger increase of those between ten and forty, whose mortality is low, takes place and counterbalances the other; whilst the proportion of old people over fifty-five years of age to the total population is diminished. A high birth-rate, therefore, continuing over a period of years, is favourable to a low death-rate, and a low birth-rate to a high death-rate. If we find—as is actually the case—that a rural district with a low birth-rate has also

a low death-rate, whilst an urban district with a high birth-rate has a high death-rate, we must conclude that the sanitary surroundings, the occupations, or the social conditions of the rural districts are more favourable to life than those of the urban. These are the main causes of the varying health conditions of populations, of which death-rates, with certain limitations, afford trustworthy evidence.

In estimating the total death-rate of a combination of two or more districts, which exhibit different mortality figures, the method of taking the average of the district death-rates, irrespective of population, would introduce a serious error.

Example.—If A has a population of 10,000 and a death-rate of 25 per 1,000; if B has a population of 2,000 and a death-rate of 10 per 1,000; and if C has a population of 7,000 and a death-rate of 15 per 1,000, the death-rate of the combined districts with a population of 19,000 is—

$$\left(\frac{10{,}000}{19{,}000}\times 25\right)+\left(\frac{2{,}000}{19{,}000}\times 10\right)+\left(\frac{7{,}000}{19{,}000}\times 15\right)=$$

$$\left(\frac{10}{19}\times 25\right)+\left(\frac{2}{19}\times 10\right)+\left(\frac{7}{19}\times 15\right)=$$

$$\frac{250+20+105}{19}=\frac{375}{19}=19{\cdot}7.$$

If, however, the average of 25, 10, and 15 had been taken, viz., 16·6, an error of 3·1 per 1,000 would have been committed.

The *mean age at death* of a population is obtained by adding together the ages at which people die, and dividing the number of years by the number of deaths. It is merely an expression of the average age at death of a population, and gives no evidence of the health or sanitary condition of the community. When a population is rapidly increasing by excess of births over deaths, the mean age at death is low, because the population is largely composed of young persons. When a population

is nearly stationary, the proportion of old people to the total population is large, and the mean age at death is high. The mean age at death, therefore, gives information as to the ages of the dying and *per contra* of the living in different communities, but nothing more.

A *life table* represents a generation of a million individuals passing through life to extinction. The generation is made to consist of identical proportions of the sexes; and each sex at every age is subjected to the same proportionate mortality as is actually found to exist in the community from the most recent data available. The mean mortality figures for a series of years should be taken, as the returns for a single year may be exceptional in character. Such tables afford the scientific basis on which the calculations for life assurance are founded, for they enable us to measure the probabilities of life and death.

The *mean duration of life* or *expectation of life at birth* differs widely from the mean age at death, when the population is continuously disturbed by a fluctuating birth-rate, immigration, and emigration, although when the population is stationary they coincide. Thus, the mean duration of life in England (1881-90) for males, as calculated from a life table, was 43·66 years; whereas the mean age at death was only twenty-nine years, whilst one in forty-five died annually. It must be borne in mind that this difference is due to the fact that the mean duration of life is calculated from life tables in which all the members of a hypothetical population are traced through life, while the mean age at death is a calculation based upon the actual registered deaths in a population disturbed by fluctuations of both immigration and emigration. The mean duration of life is found from life tables, which show how many of a given number

born live through each year of age, and what is the sum of the number of years they live ; the sum of these years divided by the lives is the mean duration of life (mean after-lifetime or expectation of life at birth). It is not the same thing as the *probable duration of life*, which is the age at which a given number of children born at the same time are reduced one-half, the chances, therefore, of their dying before or after that age being equal. The mean duration of life for males (English life table, 1881-90) was 43·66 years, whilst the probable duration of life was about 52 years.

ENGLISH LIFE TABLE, 1881-90 (ABRIDGED FROM DR. TATHAM'S).*

Age.	Males.		Females.	
	Of a million born number surviving.	Mean after-lifetime.	Of a million born number surviving.	Mean after-lifetime.
0	1,000,000	43·66	1,000,000	47·18
1	838,964	50·97	868,874	53·24
2	790,891	53·04	823,072	55·18
3	772,046	53·32	804,142	55·46
4	760,167	53·15	791,973	55·31
5	751,494	52·75	783,244	54·92
10	733,477	49·00	766,151	51·10
15	726,194	44·47	759,062	46·55
20	712,555	40·27	744,321	42·42
25	693,809	36·28	724,788	38·50
30	669,279	32·52	700,049	34·76
35	639,645	28·91	670,992	31·16
40	604,923	25·42	638,912	27·60
45	564,437	22·06	604,007	24·05
50	517,639	18·82	564,299	20·56
55	462,981	15·74	516,375	17·23
60	398,400	12·88	457,682	14·10
65	322,482	10·31	385,503	11·26
70	238,632	8·04	299,220	8·77
75	153,890	6·10	204,208	6·68
80	80,023	4·52	114,536	5·00

* Supplement to the 55th Annual Report of the Registrar-General.

From this table it will be seen that, after the first year of life, the chances of living increase up to the third year, and remain nearly as good through the fourth and fifth years. Subsequent to this age, the chances of life lessen up to fifty years of age in the ratio of from three to four years for each five lived, the greatest reduction being 4·5 years from the age of ten to the age of fifteen. After fifty the chances of life lessen more rapidly.

Mean after-lifetime is a more accurate expression than expectation of life, as, strictly speaking, the time which it is expected a person will live is the time which it is an even chance he will live; it is then strictly the probable duration of his life. It has been thought advisable to retain here the term "expectation of life," as being the term usually employed in life tables. It must be understood, however, to mean, whenever expressed, the mean after-lifetime, and not the probable duration of life.

It has been shown by the late Professor de Chaumont that the mean duration of life may be approximately calculated from the birth-rate and death-rate by the following formula: where b = birth-rate per unit of the population, and d = death-rate per unit of the population.

$$\text{Then } \textit{mean duration of life} = \left\{\frac{2}{3} \times \frac{1}{d}\right\} + \left\{\frac{1}{3} \times \frac{1}{b}\right\}.$$

This formula, however, is really only applicable when the birth and death rates do not depart much from the average of the whole country.

Dr. Tatham has shown how a figure, representing what he terms "life capital," can be obtained with the assistance of a life table. If the most recent mortality returns for a single year are compared with the mean of

those obtained for a succession of the years immediately preceding, the comparison will generally be a favourable one to the most recent year. The difference in the number of deaths will be the lives saved to the community. If each life gained be multiplied by the mean expectation of life for the corresponding age-period, we obtain the gain of life capital of the community for each age-period, and from this the gain for the whole community can be ascertained.

The latest English *life table* (Dr. Tatham's) is based upon the mean population of each sex, and at each year of age, for the decennium 1881-90, and on the total deaths for each sex at each year of age during the same period. Then the rate of mortality per unit of the male or female population at any age $x =$

$$\frac{\text{number dying at age } x}{\text{mean population at age } x} = m_x.$$

The mean population at the age x is the precise number returned as living at the age x less one-half of the deaths occurring in the ensuing year. The probability that a person of the precise age x will survive one full year $=$

$$\frac{\text{number of survivors at end of year } x}{\text{number living at beginning of year } x} = p_x;$$

Thus, starting with a certain number (l) at birth, if l is multiplied by the probability of living one year, the number surviving at the end of the year is obtained. Similarly, the number living at the end of the second year is obtained by multiplying the number commencing the year by the probability of their surviving the year, and so on. In this way, commencing with a certain number at birth, the number surviving at each year of age up to a hundred or more years can be ascertained and entered in the life table column (see "Vital Statistics," A. Newsholme, M.D.).

Life tables, besides giving the numbers surviving at all ages from a million born at one and the same time, also enable the mean duration of life or the expectation of life at birth to be calculated, as well as the mean after-lifetime or the expectation of life at any age—that is, the length of time a person of any age may be expected to live. The expectation of life at any age is calculated from the numbers living at the age in question (given in the life table) and from the years of life they subsequently live, just as is the mean duration of life (expectation of life at birth). For ages between twenty-five and seventy-five, Willich's formula also gives approximate results.

If x = expectation of life, and a = present age, then $x = \frac{2}{3}(80 - a)$.

Life tables afford an excellent test of the health of a community. By the English table for 1881-90, the expectation of life at birth for males is 43·66 years; whereas it was 41·35 by the table of 1871-80, and 39·91 by the 1838-54 table. Among females, the expectation of life was 41·85 and 44·62, respectively, in the two earlier tables, and 47·18 by the new table. The expectation of life increases every year in both sexes up to the third year, when it is 53·32 for males and 55·46 for females, the dangers to life of the period of infancy being then passed. Subsequent to the third year, the expectation of life gradually decreases for each year of age. The expectation of life for all ages up to forty-four years is higher by the recent table (1881-90) than by the previous one (1871-80). But after the age of forty-four the expectations of life are slightly higher by the old table than by the new.

As compared with the older life table of 1838-54, the expectation of life for males by the most recent table is only higher up to the age of twenty-six years,

and beyond that age is lower. For females the most recent table shows an expectation of life higher up to the age of forty-four, as compared with the 1838-54 table. The causes of this alteration in figures between the newest and oldest life tables appear to be that by improved sanitary surroundings the lives of infants and children have been saved in the recent period which were sacrificed in the former, thus increasing the expectation of life during childhood, youth, and early manhood. After reaching adult age, males are now subjected to conditions which are not more favourable to life—probably less so from increased competition and difficulty in gaining a livelihood—than existed between 1838-54; and this, together with the fact that some of the lives saved in childhood are probably unhealthy ones, which would have perished under the old insanitary conditions, accounts for the expectation of life being now actually less for adults over twenty-six years of age than formerly. Females, not being subject to the same conditions as males, and living more at home, are likely to derive benefit from improved sanitation after reaching adult age, as is indeed plainly shown by the life tables. After the age of forty-five, however, the unhealthy female lives saved in infancy begin to influence the expectation of life.

Although by the male life table the expectation of life after twenty-six years is less now than fifty years ago, the numbers living at each year of age up to seventy-nine years are greater by the 1881-90 table than by the 1838-54 table; after seventy-nine the numbers living are less. By the female life table the numbers living up to the age of eighty-nine are greater by the new than the old table. It is thus seen that there has been a great saving in life, in recent years, of males and females up to ages which embrace practically the entire lifetime.

Although out of a given number of children born more survive and reach the later age-periods than formerly, it must not be thought that individual life is lengthened; for, as the life tables show, individual life is shortened after reaching a certain age in both sexes, the reduction in the expectation of life being due to an increased mortality during the later age-periods.

The reasons for stating the death-rates of males and females separately, and at groups of ages, as well as the death-rate for all ages and both sexes, when it is necessary to compare the vital statistics of different communities, will now be understood. The death-rates of infants under one year, and of children under five years, are most important, as they afford very positive evidence of the sanitary condition of a community. The death-rates of infants under one year should be stated as so many deaths in a year to 1,000 registered births, this rate being known as the "rate of infantile mortality."

The *rate of infantile mortality* is liable to considerable fluctuations year by year, the fluctuations being largely determined by the increased or diminished incidence of summer diarrhœa. The rate in this country furnishes no evidence of any continuous reduction, and the deaths under one year of age still continue to form some 25 per cent. of the total deaths. The chief registered causes of infantile mortality are as follows: Debility, inanition and prematurity of birth, diarrhœa and dysentery, measles and whooping-cough, convulsions, accidents (including "overlying"), bronchitis and pneumonia. Seventy per cent. of the total infantile mortality is generally ascribed to the above-mentioned causes. The rate of infantile mortality among illegitimate children is about double that of children born in wedlock.

For England and Wales, in the ten years 1881-90, the

average number of deaths of male infants under one year to 1,000 births was 155, of female infants 128, and of both sexes 142.

The deaths of children under five should be stated as death-rates per 1,000 living under that age. The average rate for male children for England and Wales (1881-90) was 61·69 per 1,000, for female children 51·99 per 1,000, and of both sexes 56·82. No doubt some for this infant and child mortality, which is preventable, is due to other causes than insanitary conditions controllable by local authorities, such other causes being maternal neglect, insufficient and improper nourishment, etc. Still, just as Dr. Farr said a sustained rate of general mortality above 17 per 1,000 always implies unfavourable sanitary conditions, so it may be said that rates of mortality amongst infants and young children, which exceed the rates prevalent in the country generally, are mainly indications of bad sanitary conditions in the communities in which they occur.

The system of certification of the cause of death—although still very incomplete, both from errors in diagnosis and improper nomenclature, and from want of certification amongst the very poor in large cities—enables the death-rates from special diseases, or groups of diseases, to be stated with some approach to accuracy.*

* The best statistical evidence of the health of a community is, of course, furnished by the corrected death-rate, although a sick-rate ("morbidity-rate") would furnish still better evidence. The registration of sickness, however, would be open to many fallacies and abuses. The scant returns which are available in this country (*i.e.*, from sick clubs, friendly societies, industrial organizations, hospitals, army, navy, police, etc.) are only concerned with disabling sickness, among what are often selected lives, and are of little value for the purpose under consideration. On an average, there are two years of sickness suffered to each death registered.

The death-rates from the principal zymotic diseases, from tuberculosis, phthisis, and acute diseases of the lungs, afford most valuable evidence of sanitary condition. The seven principal zymotic diseases of the Registrar-General are: small-pox, measles, scarlet fever, diphtheria, whooping-cough, "fever" (*i.e.*, typhus, enteric fever, and simple continued fever), and diarrhœa. Of these, enteric fever mortality is the best test of sanitary condition, caused as it is by specific fæcal contamination of soil and water; whilst diarrhœa, with its special incidence on young children, is notably associated with insanitary surroundings. The other zymotic diseases, although probably favoured in their onset and fatality by unhygienic conditions, also indicate, when the mortality

Annual Death-rate per 1,000 in 1871-80, 1881-90, and 1891-95.

	England and Wales (Persons).		
	1871-80.	1881-90.	1891-95.
All causes	21·27	19·08	18·73
Small-pox	0·23	0·045	0·020
Measles	0·38	0·44	0·40
Scarlet fever	0·72	0·33	0·18
Diphtheria	0·12	0·16	0·25
Whooping-cough	0·51	0·45	0·39
Typhus	0·06	0·015	0·004
Enteric fever	0·32	0·20	0·17
Simple continued fever	0·10	0·025	0·008
Diarrhœa and dysentery	0·93	0·67	0·65
Zymotic diseases	3·47	2·36	2·07
Phthisis	2·12	1·72	1·46
Other tubercular diseases	0·75	0·70	0·66
Diseases of the respiratory system	3·9	3·73	3·74
Cancer	0·46	0·58	0·71

from them is high, a failure on the part of the sanitary authority to control their spread by disinfection and isolation. Tuberculosis, phthisis, and acute diseases of

the lungs, are most prevalent and most fatal amongst communities where overcrowding in dwellings or workshops is allowed to exist, or where sites are damp and the subsoil saturated with water. They may thus be taken as evidence of a certain class of insanitary conditions, usually associated with poor town populations. The rate of infantile mortality, though influenced solely by conditions affecting those under one year of age, also ranks high as evidence of the health of a community.

The number of deaths at a special age-period must not be stated as a proportion of the total population, nor must the deaths from a special disease be stated as a proportion of the total deaths from all causes; for a fallacy is involved in attempting to establish a relationship between two factors, both of which are variable. The number of deaths at a certain age-period must be expressed as a proportion of the number living at the age in question, this number—as we have seen—varying considerably in different communities. The special disease, also, may be one affecting chiefly a certain age-period and sex, and a like error will be involved if the rate is not expressed as per 1,000 of the population living at the same ages and of the same sex as those attacked. Dr. Ransome gives the following example of the fallacious character of such statements:*

A town A has a population of 100,000 with 2,000 annual deaths, of which 500 are caused by phthisis. A town B has a population of 100,000 with 4,000 annual deaths, of which 1,000 are due to phthisis. The general death-rate of A is 20 per 1,000, of B 40 per 1,000. A's death-rate from phthisis is 5 per 1,000, B's is 10 per 1,000; but the proportion of deaths from phthisis to total deaths is 250 to 1,000 in the case of both A and B;

* "Vital Statistics," by A. Newsholme, M.D.

and judging from this test alone, A would appear to suffer as severely from phthisis as B, although as a matter of fact its death-rate from phthisis is only half B's.

Again, more than 90 per cent. of the deaths from scarlet fever occur among children under ten years of age. Now, children under ten amount to 25 per cent. of the population in Berlin, but only to 12·4 per cent. of that of Paris. An equal death-rate from scarlet fever in the two cities would, therefore, imply a mortality twice as great in Paris as in Berlin.

The annual birth-rate in England and Wales is now about 30 per 1,000 (in 1899 it was 29·2). The birth-rate has steadily declined since the year 1876, when it was 36·3 per 1,000, and the highest recorded rate of any year since civil registration began (1839). The now prevailing rate is lower than that of any year in the same period (1839-90).

In 1898, 16·3 persons were married per 1,000 of the population in England and Wales. The marriage-rate fell continuously from the year 1873 (17·6 persons married per 1,000) to the year 1886 (14·2 per 1,000), but has since risen again.

The lowest annual death-rate in England and Wales ever recorded since civil registration began was in the year 1894, the rate being 16·6 per 1,000. A higher mortality prevailed in the four years 1890, 1891, 1892, and 1893, the average death-rate being 19·5 per 1,000, which is attributable to the prevalence of influenza in those years and a great fatality from lung diseases, the sequelæ of influenza.

The average annual death-rate of the ten years 1861-70 was 22·5 per 1,000; of the ten years 1871-80, 21·3 per 1,000; and of the ten years 1881-90, only 19·1 per 1,000. Although to a great extent this lowered death-rate must

be credited to the operation of the Public Health Acts, and the more stringent application of these Acts and of local by-laws, still, it must not be forgotten that the lowered birth-rate would conduce to a lowering of the death-rate for some few years at least, as the proportion of children under five years of age, whose death-rate is high, would be diminished, and the ratio of older children and adults to the entire population would be increased. If the birth-rate continues to fall, as it has done in the last twenty years, we may expect the death-rate eventually to rise again, owing to the increase in the mean age of the population, and a consequently increased ratio of old people (over fifty-five years) to the total population.

It is a remarkable fact that the death-rate in town or urban districts has declined to a greater extent than that in rural districts, as the following table (from the 53rd Annual Report of the Registrar-General) shows:

Years.	Death-rate per 1,000 Persons living.		
	England and Wales.	Town Districts.	Country Districts.
1851-60	22·2	24·7	19·9
1861-70	22·5	24·8	19·7
1871-80	21·4	23·1	19·0
1881-90	19·1	20·3	17·3

Whilst in 1861-70 there were 126 deaths in town districts to every 100 deaths in country districts for equal numbers living, and in 1871-80 there were 122 deaths in towns to 100 in the country, in 1881-90 there were only 117 deaths in towns to 100 in the country. This means that sanitary measures carried out in towns,

where they were most needed, have done more to prolong human life than in the country, and that sanitary improvements have been undertaken with greater vigour and thoroughness in urban than in rural districts.

The following table indicates the differences in the general death-rates and in the rates of the seven principal zymotic diseases in 1897 in England and Wales generally, and in England and Wales less the 100 chief towns:

	England and Wales.	England and Wales *less* the 100 Chief Towns.
All causes	17·4	16·4
Principal zymotic diseases	2·15	1·62
Small-pox	0·00	0·00
Measles	0·40	0·29
Scarlet fever	0·14	0·12
Diphtheria	0·24	0·19
Whooping-cough	0·35	0·31
Fever	0·16	0·14
Diarrhœa	0·86	0·57

It is very necessary, in comparing the death-rates in town and country districts respectively, to correct for the very different age and sex distributions in the country and in towns, which are due to the immigration of those in the middle age-periods from the country districts into the towns with the object of finding employment there at better wages.

The leading causes which serve to raise the death-rates of towns above those in country districts are as follows: Overcrowding, which directly causes disease and promotes the spread of communicable illness, especially summer diarrhœa, measles, and phthisis; the higher birth-rates, attended with a higher rate of infantile mortality; the less healthy occupations; the greater amount of profligacy and intemperance; the larger

number of accidents; the existence of many public and private institutions for the reception of the sick, which attract people from the neighbouring rural districts, and the fact that the deaths occurring in these institutions are not always allotted to the districts from which the sufferers came.

The importance of a right use of vital statistics, and of avoiding unfounded and erroneous deductions, is so great that it will be well to further indicate some of the errors and fallacies, which are either inseparable from, or are introduced into the subject.

In the first place, the data derived from the census returns are incomplete and sometimes fallacious: *e.g.*, old people are often ignorant of their precise age, and frequently overstate it when very old; females often wilfully misstate their ages; and young children are often returned as one or two years old when they are only in their first and second years. Again, the population is only an estimate in the intercensal periods, and considerable errors in the estimation often arise; it is for this reason especially that a five-yearly census is so much to be desired. The registration of births and deaths, and the certification of the causes of deaths, are subject to many fallacies, arising from faulty diagnosis, indefinite certification, and the lack of uniformity in the nomenclature of disease; whilst many births escape certification from ignorance, shame of illegitimacy, or from the parents' desire to avoid vaccination. The use of such terms as "convulsions," "jaundice," and "dropsy," for instance, should be avoided, whenever the true cause of these symptoms can with reasonable certainty be substituted. It is impossible, also, to correctly classify deaths which are returned as due to two or three distinct maladies, without any indication as to which was the primary cause of

death. Various classifications of deaths have been suggested and employed; they may be based on symptoms, causes, the tissues and organs affected, or the parts of the body affected considered anatomically. The latter is the classification suggested by Farr and Bertillon; and it would probably insure a greater precision in classification, and favour a more just comparison of the deaths from various causes than any other.

The death-rate of seaside places is seldom correct. A certain number of visitors are always included in the estimation of the population, and it is not easy to exclude the deaths of visitors. The domestic servants in a community introduce a further fallacy in vital statistics, since they rarely die in service. Although counted in the population of the district where they reside, they frequently return to their homes in rural districts, when seriously ill and unfit for further service.

The death-rates of general hospitals can never be justly compared, because of the varying nature and gravity of the cases admitted from time to time, the varying proportion of medical to surgical beds, etc. The death-rate is often stated as the number of deaths to every 100 occupied beds, but it is better to express the deaths as a ratio of the number of cases treated to a termination.

Occupation plays an important part in determining mortality, some occupations being far more healthy than others. *Occupational mortality* is calculated from the deaths occurring in any particular occupation. For purposes of comparison the death-rates among those employed at corresponding age-periods must be taken, allowance being thus made for the varying age-constitution of those engaged in the different occupations. A *comparative mortality figure* for different occupations may

be obtained by taking the deaths occurring in a *standard population*, such standard population to consist of the exact number of males in the whole population between twenty-five and sixty-five years of age who would supply 1,000 deaths annually.

Dealing with the deaths of 1890-92 and the population of 1891, Dr. Tatham shows that 1,000 deaths occurred among 62,215 males between twenty-five and sixty-five years of age; whereas the number of deaths among a similar number of medical practitioners only amounted to 966; or, in other words, the same number of men aged twenty-five to sixty-five (having equal numbers at the various inclusive ages), that would furnish 1,000 deaths among all males, would only give 966 among medical practitioners.

An obvious fallacy in any attempt to gauge the relative healthiness of different occupations results from the fact that certain trades attract the more robust and muscular, whilst others demanding less strength attract the weaklings.

The mean age at death cannot be taken as an index of the healthiness of an occupation, because some employments are filled by older men, who have proved their worth or have filled minor posts during many years, while other classes of labour, requiring less skill and experience, are much more largely filled by those younger in life.

Instances of the more usually employed graphic methods of representing statistical results can be seen in the annual reports of medical officers of health. Erroneous conclusions are apt to be formed by comparing the mortality curves on scales which are not identical. "Spot maps"—maps of the district, on which the deaths or cases of various infectious diseases are

spotted out—furnish valuable graphic expressions of any grouping of such deaths or sickness, and are much employed by medical officers of health. They should, however, usually be employed to express the occurrences of short periods only. Spot maps, covering a period of several months or a year, are not often of much value for the purpose which they are designed to subserve.

CHAPTER XII.

SANITARY LAW AND ADMINISTRATION

SANITARY AREAS AND AUTHORITIES.

BY the Local Government Act, 1894, England and Wales are divided into — (1) administrative counties, (2) county boroughs. The administrative counties (outside London) are divided into urban and rural districts.

The following table shows the areas, the authorities, and the chief Acts having relation to public health which the sanitary authorities administer :

Area.	*Authority.*	*Sanitary Acts administered.*
Administrative County	County Council	Appeal Authority under Local Government Act, 1894, and under section 299, Public Health Act, 1875. Rivers Pollution Prevention Act, 1876. Isolation Hospitals Act, 1893.
County Borough Municipal Borough Urban District (of County)	Town Council Municipal Council Urban District Council	Local Sanitary Acts. Public Health Act, 1875. Public Health Acts Amendment Act, 1890 (adoptive). Sale of Food and Drugs Acts, 1875, 1879, and 1899. Margarine Act, 1887. The Sale of Horse-flesh Act, 1889. Canal Boats Acts, 1877, 1884. Public Health Interments Act, 1879. Factories and Workshops Acts, 1878-1895, so far as relates to sanitation. Housing

Area.	*Authority.*	*Sanitary Acts administered.*
		of the Working Classes Act, 1890, 1899. Infectious Diseases Notification Act, 1889. Infectious Diseases Prevention Act, 1890 (adoptive). Dairies, Cowsheds, and Milkshops Orders, 1885, 1886, 1899. Rivers Pollution Prevention Act, 1876. The Cleansing of Persons Act, 1897.
Rural District (of County)	Rural District Council	All the Acts above cited as administered by Urban Sanitary Authorities, with the exception of certain sections of the Public Health Act, 1875, and of Part I. of the Housing of the Working Classes Act. Public Health (Water) Act, 1878.
Parish, forming part of a Rural District	Parish Council	Certain sanitary powers under the Local Government Act, 1894, section 8, but not in substitution of those exercised by the Rural District Council.
Port	Port Sanitary Authority	Assigned by the Local Government Board, and practically those of an Urban Sanitary Authority. Regulations of the Local Government Board. The Public Health (Ships) Act, 1885.
County of London Metropolitan Boroughs	London County Council Borough Councils	The Metropolis Local Management Acts, Public Health (London) Act, 1891, etc.

Port Sanitary Authorities.

Under the Public Health Act, 1875, section 287, the Local Government Board may by order constitute any sanitary authority, or a combination of sanitary authorities, whose district or districts abut upon any port in England or Wales, the port sanitary authority, either temporarily or permanently. The order may assign to the port sanitary authority any of the powers, duties, etc., of an

urban sanitary authority, so far as applicable to a port, and to vessels, waters, or persons within its jurisdiction. These duties include the appointment of a medical officer of health and of an inspector of nuisances, the duties of the former being prescribed by a special Order of the Local Government Board. In addition, this officer has to carry out the Board's cholera regulations of 1890 and 1892, and any regulations made by the Board prohibiting the importation of rags from infected foreign ports, or requiring that they shall be disinfected or destroyed to the port medical officer's satisfaction (1893 Order). The disinfection must be by steam. Dirty and disused bedding or clothing arriving from certain ports, whether belonging to emigrants or otherwise, can only be landed for destruction or disinfection.

Medical Officers of Health and Sanitary Inspectors.

By the Public Health Act, 1875, section 189, every urban and rural sanitary authority is required to appoint a medical officer of health and an inspector of nuisances; but two or more districts may be combined by the Local Government Board to form a combined sanitary district, with one set of officers for the whole combination. County Councils under the Local Government Act, 1888, section 17, may appoint a county medical officer of health.

If any part of the salary of a medical officer of health is repaid to a local authority out of Imperial funds, the Local Government Board has the same power of approval of his qualifications, appointment, duties, salary, and tenure of office, as it has in the case of a poor-law medical officer (Public Health Act, 1875, section 191).

By section 18 of the Local Government Act, 1888, every medical officer of health appointed after the passing of the Act must be legally qualified in medicine, surgery, and midwifery; if appointed after January 1, 1892, to a district having at the last census 50,000 inhabitants or more, he must be the registered holder of a diploma in public health under section 21 of the Medical Act, 1886, or have been during some three consecutive years prior to 1892 a medical officer of health of a district with a population at the last census of not less than 20,000, or have been for not less than three years a medical officer or inspector of the Local Government Board.

If no part of the salary of the medical officer of health is repaid, the Local Government Board need not be consulted, nor is their approval necessary as regards qualifications, appointment, salary, or tenure of office. If a portion of the salary is repaid, the medical officer cannot be removed except with the sanction of the Board,

and if suspended the Board may remove the suspension. The duties of both classes of officers are the same under the Local Government Board's regulations of March 23, 1891.

In London every medical officer of health must reside within his district, or within one mile of its boundary. He must not be appointed for a limited period only, as may be done outside London. He is removable by the Local Government Board, as well as by his sanitary authority, with the consent of the Local Government Board. In other respects the post is similar to that of an extra-Metropolitan officer as regards appointment, qualifications, tenure of office, and duties.

In London every sanitary inspector appointed after January 1, 1895, must be a holder of a certificate of an examining board approved by the Local Government Board, or must have been during three consecutive years preceding 1895 an inspector of a district containing a population of not less than 20,000. Outside London there is no qualification required by statute for inspectors of nuisances.

In London every sanitary authority is required to appoint an adequate number of fit and proper persons as sanitary inspectors; and the London County Council has power to insist upon a sufficiency of inspectors for each district in the county.

By-laws and Regulations.

Under the various statutes relating to public health, sanitary authorities have power to make by-laws. These *by-laws* should supplement, not vary or supersede, the express provisions of the statutes. If repugnant to the laws of England or to the provisions of the Acts, they are *ultra vires* and of no effect. Reasonable penalties may be provided for in the by-laws for neglect or infringement of their requirements. All by-laws must be confirmed by the Local Government Board, and when so confirmed have the force of law. *Regulations* do not, as a rule, provide for the infliction of penalties, and they do not require confirmation by the Local Government Board. Both by-laws and regulations are usually drafted upon models issued by the Local Government Board.

Every urban sanitary authority must make by-laws in respect of common lodging-houses and slaughter-houses, and every rural sanitary authority must make by-laws in respect of the former. With respect to all other matters on which by-laws may be made, it s optional to do so, unless required by the Local Government Board. Both urban and rural authorities may make by-laws in respect of

cleansing and scavenging; tenement houses occupied by members of more than one family; hop and fruit pickers; tents and vans; and mortuaries. Urban authorities may in addition make by-laws for new streets and buildings, markets and fairs, offensive trades, open spaces, and cemeteries. Urban powers may be granted by the Local Government Board to rural authorities, including the making of by-laws; and the adoption of the Public Health Acts Amendment Act, 1890, enables a rural authority to make certain by-laws in respect of new and old buildings.

Regulations may be made by any sanitary authority under the Dairies, Cowsheds, and Milkshops Order with respect to dairies and cowsheds; also under the Public Health Act, 1875, for the management of post-mortem places provided by the authority; and under the same Act for the removal to, and detention in, hospital of infectious patients taken off ships and vessels.

In London the County Council has power to make by-laws for a great variety of purposes relating to new streets and roads, plans and sites of buildings, drains and sewers, etc., under the Metropolis Local Management Acts and London Building Act, 1894. Under the Public Health (London) Act both the County Council and the local sanitary authorities are required to make by-laws on a variety of subjects, which will be alluded to in their proper place.

Sewers.

Public Health Act, 1875.

Definition.—Sewer includes sewers and drains of every description, except drains of, and used for the drainage of, one building only, or premises within the same curtilage. It follows from this definition that sewers may be on private land, as well as in or beneath streets or highways which are dedicated to the public. A pipe, conduit, or channel receiving the drainage of more than one building, situated on or beneath land to which the public have no rights of access, and with which no drain connections can be made by owners of adjacent houses, is a sewer (Travis *v.* Uttley). The meaning of the word 'curtilage' is obscure, although it is generally held to signify the boundary wall of the premises. The shops in the Lowther Arcade, London, were held not to be within the same curtilage (Vestry of St. Martin *v.* Bird), but blocks of artisan dwellings, separated from each other by an open causeway, were held to be within the same curtilage (Pilbrow *v.* Vestry of Shoreditch).

All sewers, with the exception of certain private sewers, are

vested in the local authority. The local authority must keep all sewers under their control in repair, and must make such sewers as may be necessary for effectually draining their district. They must cause the sewers under their control to be so constructed, ventilated, and cleansed as not to be a nuisance or injurious to health (sections 13, 15, 19).

Where complaint is made to the Local Government Board that a local authority has made default in providing their district with sufficient sewers, or in the maintenance of existing sewers, that Board can compel the local authority to perform its duty in the matter of such complaint (section 299).

The owner or occupier of any premises within the district of a local authority is entitled to drain his house into a sewer after due notice, and on condition of complying with the local authority's regulations for the making of communication between sewers and drains (section 21).

Section 26 prohibits the erection of any building over a sewer of an urban authority without the written consent of such authority. This section applies to combined drains which are sewers on private land, as well as to sewers in public roads and highways.

Public Health Acts Amendment Act, 1890 (*adoptive*).

In places where this Act has been adopted, where two or more houses belonging to different owners are connected with a public sewer by a single private drain (that is to say, a drain on private land with which adjacent house-owners are not at liberty to make drain connections), and the local authority has reason to believe that such drain is defective or a nuisance, the local authority can, under the powers conferred by section 41 of the Public Health Act, 1875, after twenty-four hours' notice to the occupiers, proceed to open the ground and expose the drain, and, if found defective, execute such works as may be necessary to make the drain secure and sound, and recover the expenses so incurred from the owners of the houses. For the purposes of this section, therefore, under the Amendment Act of 1890, the drain of more than one building, where the buildings belong to different owners, is a drain for which such owners are responsible; but if the different buildings belong to one owner, such drain is a sewer, for which the local authority are responsible.

Sections 16 and 17 of the same Act prohibit the introduction into any sewer of any matter which would interfere with the flow of the

sewage, or by which the sewer may be injured, and prohibits the introduction of any chemical refuse or liquids of any kind having a temperature exceeding 110° F., which either alone or in combination with the sewage cause a nuisance, or are dangerous or injurious to health.

Metropolis Local Management Acts, 1855 *and* 1862.

In London the definition of sewer is the same as in the provinces under the Public Health Act, 1875, with the exception that the combined drain of a group or block of houses, drained by a combined operation under the order or with the sanction or authorization of a vestry or district board of works (or, prior to 1855, of the Metropolitan Commissioners of Sewers), is a drain for which the owner or owners of the houses are responsible, and not a sewer (1855 Act, section 250; 1862 Act, section 112). Recent decisions of the High Court of Justice and of the Appeal Courts have shown that if the scheme of drainage sanctioned by the authority has been departed from in material particulars, or if the drains of other houses have been connected surreptitiously, or without authorization, subsequent to the passing of the plans, the combined drain is a sewer, and repairable by the local authority. In fact, no combined drains, except those which have been sanctioned by authority, and which at date practically conform with the plans passed by the authority, are drains; they are sewers, repairable by the ratepayers at large.

The control of the main sewers in London and of the disposal of the Metropolitan sewage is vested in the London County Council, whilst the street and other branch sewers are vested in the vestries and district boards (now the municipal councils), with whom lies the regulation of the method of making communications between all house drains and sewers. As in the provinces, there is a penalty imposed for building over any sewer or interfering with any sewer without the consent of the local authority; and there is a prohibition from discharging into any sewer any matters which would interfere with the flow of the sewage, or any liquids which would damage the sewer or create a nuisance.

Disposal of Sewage.

Section 17 of the Public Health Act, 1875, expressly states that nothing in the Act shall authorize the discharge of sewage into any natural stream or water-course until the sewage has been freed from

all excrementitious or other foul or noxious matter. Sections 27 to 34 of the same Act give powers to local authorities to construct works for the disposal of sewage, either within or without their districts. For this and other purposes local authorities can borrow money on the credit of the rates, subject to the sanction of the Local Government Board (section 233). The regulations applicable to the exercise of borrowing powers, which must be complied with, are set out in section 234 of the Act.

Rivers Pollution Prevention Act, 1876.

By section 7 of this Act sanitary authorities must give facilities to manufacturers to carry their waste waters into the district sewers, provided such waste waters do not affect prejudicially the sewers, or the disposal of the sewage on land or otherwise at the outfall, or are not themselves injurious from a sanitary point of view or by reason of high temperature. There is no obligation on sanitary authorities to construct new sewers to receive manufacturing waste, if their existing sewers are only just sufficient for the ordinary requirements of the district, and are unable to receive larger volumes of manufactory refuse.

House Drains.

Public Health Act, 1875.

By section 23, a local authority can require the owner or occupier of any house which is within their district, and which is "without a drain sufficient for effectual drainage," to make a drain to empty into any sewer which the local authority is entitled to use (for this purpose), which is not more than 100 feet from the site of such house—*i.e.*, from the boundary of the land on which such house is situate. If no such sewer is situate within 100 feet of the boundary, then the drain may be made to empty into a covered cesspool or other receptacle, not being under any house, as the local authority may direct. Such drain or drains must be of such material and size, and laid at such levels and with such fall, as the surveyor to the local authority may direct.

By section 25, urban authorities can insist on newly erected houses, or houses which have been rebuilt after being pulled down to the ground-floor, being drained in a similar manner to the above. No newly erected or rebuilt house may be occupied until a proper drain has been provided.

The examination or testing of drains (not involving the opening

of the ground) is provided for by section 102 of the Act, which directs that any officer of a local authority shall be admitted into any premises between the hours of 9 a.m. and 6 p.m. for the purpose of examining as to the existence of any nuisance thereon. If it is necessary to open the ground to examine the state of a drain, a written application must be made by some person to the local authority, stating that the drain of the premises in question is a nuisance or injurious to health. The local authority must then in writing empower their officer, after twenty-four hours' written notice to the occupier of the premises, or in case of emergency without notice, to enter such premises and open the ground. In the event of the drain being defective, notice is to be served upon the owner or occupier to carry out the necessary works; or the local authority may itself execute the works, and recover the costs so incurred from the party or parties who are liable (section 41).

Section 40 of the same Act requires every local authority to provide that all drains within their district are constructed and kept so as not to be a nuisance or injurious to health.

By section 157 of the Act, urban authorities may make by-laws with respect to the drainage of buildings, but such by-laws cannot be made to apply to any building erected in any place which, on August 11, 1875, was included in an urban sanitary district before the Local Government Acts came into force in such place, or any building erected in any place which, on that date, was not included in any urban district before such place became included in an urban district, by virtue of any order of the Local Government Board. In places where the Public Health (Amendment) Acts, 1890, Part III., has been adopted, section 23 extends the operation of drainage by-laws to buildings erected before the time above mentioned, and also enables rural authorities to make such by-laws.

It must be clearly understood that drainage by-laws—that is to say, by-laws specifying the materials from which drains are to be constructed, their jointing, gradients, ventilation, disconnection, methods of connecting branches, etc.—cannot be made to apply to existing drains or to drains of existing buildings. They are applicable to drains about to be laid for new or old buildings—*i.e.*, to new drains of new buildings or to new drains of old buildings, which for one reason or another are about to be redrained. Existing drains cannot be condemned and new drains required because they—the existing drains—do not comply in whole or in part with the regulations contained in drainage by-laws. Where existing drains are found to be so defective that they cannot be repaired so as to

render them sound, and obviate present and future nuisance, notice can be served for them to be relaid. In such a case it is probable that a local authority can insist on the new drain complying with their drainage by-laws.

Metropolis Local Management Acts and Public Health (London) Act, 1891.

Practically the same provisions exist in London for dealing with house drainage as in the provinces.

The Metropolis Management Act, 1855 (section 202), gave powers to the Metropolitan Board of Works to make drainage by-laws, which were never exercised. The successors of the Board of Works —the London County Council—has drafted such by-laws, but they have not yet been officially promulgated. Every vestry and district board (each municipal borough) has drainage regulations applicable to its particular district, prepared under powers presumed to be conveyed by sections 73, 75, and 76 of the Metropolis Local Management Act, 1855.

Section 15 of the Public Health (London) Act imposes a £5 penalty on any person who *wilfully* destroys, or damages, or stops up, or interferes with, any drain, so as to cause it to be a nuisance or injurious or dangerous to health—a section very useful in restraining the acts of mischievous or evil-disposed persons.

Section 42 of the same Act imposes a £20 penalty on any person who so repairs or constructs a drain as to cause it to be a nuisance, or injurious or dangerous to health—again a most useful section in preventing scamped or defective work.

Water-closets, Sanitary Conveniences, and Sanitary Fittings.

Public Health Act, 1875.

Every house within the district of a local authority must have a sufficient water-closet, earth-closet, or privy, and an ashpit, furnished with proper doors and coverings; and no house may be erected or rebuilt without similar sanitary accommodation (sections 35 and 36).

It is for the local authority, acting on the advice of its officers, to determine in each case what constitutes the sufficiency of a water-closet, earth-closet, or privy. Under these sections a proper supply of water to flush a water-closet can be enforced. As regards the conversion of privies into water-closets—a policy now largely

taken up in the "privy" towns of the Midland and Northern counties—the local authority has no power to make a general order enforcing the replacement of privies by water-closets, but has power in any particular case to require the conversion, if satisfied that the privy is not sufficient for the health requirements of the people who use it (Tinkler *v.* Wandsworth Board of Works).

Under section 157, urban authorities are empowered to make by-laws as to water-closets, earth-closets, privies, ashpits, and cesspools, in the same way as to drains (see *ante*, p. 676); and these by-laws are extended in the same way by the Public Health Acts Amendment Act, 1890.

Every local authority must provide that all water-closets, earth-closets, privies, ashpits, and cesspools are constructed and kept so as not to be a nuisance or injurious to health; whilst the provisions of section 41 apply equally as for drains where it is desirable to open the ground—*e.g.*, for the examination of a privy or cesspool (see *ante*, p. 676).

Public Health Acts Amendment Act, 1890.

Section 21 imposes a 10s. penalty on any person who injures or improperly fouls a sanitary convenience which is used in common by the occupiers of two or more separate dwelling-houses, or by other persons; and a similar penalty, with a daily 5s. penalty, is imposed upon all persons using a common closet which is in such a filthy condition as to be a nuisance or annoyance, from want of proper cleansing, in the absence of proof as to who is the person actually in default.

Public Health (*London*) *Act*, 1891.

Very much the same provisions apply in London as in the provinces. The County Council has made by-laws under section 39 of the Act which apply to all new fittings in new or in existing buildings (water-closets, soil pipes, earth-closets, ashpits, cesspools, dung receptacles, and their accessories). As before said (see p. 676), existing sanitary fittings must not be condemned because they do not conform to the by-laws, but all new fittings to replace existing ones must comply with the by-laws. In addition, every person who intends to fix a new water-closet, earth-closet, etc., is required to give notice of such intention to the local authority (municipal borough). Every local authority (municipal borough) has made by-laws under the same section (39, 2) with respect to the keeping of water-closets supplied with sufficient water for their effective

action. Sections 15 and 42 of the Act (see p. 677) apply equally as in the case of drains, whilst section 46 incorporates section 21 of the Public Health Acts Amendment Act, 1890, above mentioned. Any person who thinks himself aggrieved by any notice or act of a sanitary authority under these sections may appeal to the London County Council, whose decision shall be final.

Nuisances.

Public Health Act, 1875.

The nuisances with which public health Acts are concerned are conditions which are either actually injurious to health or are liable to be injurious (*i.e.*, dangerous) to health. These conditions are more or less defined in the Acts relating to public health; hence these nuisances are also called "statutory nuisances." These Acts provide the methods and machinery for summarily (*i.e.*, expeditiously) dealing with this class of nuisances, but this does not exclude the invoking by any person aggrieved of the Common Law statutes should he not be satisfied with the remedies provided by the special Acts. Nuisances which interfere with comfort or with the enjoyment of life, and are not *ejusdem generis* with those specifically mentioned in the Public Health Acts, having no obvious relation with dangers to health, are only remediable by the ordinary operations of the Common Law, and not by the public health statutes.

Nuisances are defined in section 91 of the Public Health Act, 1875:

1. "Any premises in such a state as to be a nuisance or injurious to health." The word "premises" includes "messuages, buildings, lands, easements, and hereditaments of any tenure." It has been very generally held that it is not necessary to prove actual injury to health, but simply to prove that the nuisance is of such a nature as to be capable of acting prejudicially upon health. For instance, damp, dirty, and dilapidated premises, or houses invaded by bugs or other vermin, are nuisances under this subsection, because they are all capable of affecting injuriously the health of the occupants.

2. "Any pool, ditch, gutter, water-course, privy, urinal, cesspool, drain, or ashpit so foul or in such a state as to be a nuisance or injurious to health." Under this subsection, a very great deal of the sanitary work of local authorities is carried on. The enforcement of the paving of yards and areas about houses is usually required under this subsection, to obviate nuisance from standing pools of dirty water.

3. "Any animal so kept as to be a nuisance or injurious to health."

4. "Any accumulation or deposit which is a nuisance or injurious to health." Trade or manufactory deposits are exempt, if not kept longer than necessary for the purposes of the business, and if the best available means have been taken to obviate injury to health.

5. "Any house or part of a house so overcrowded as to be dangerous or injurious to the health of the inmates, whether or not members of the same family." From 300 to 400 cubic feet per head is usually taken as the minimum permissible, with half these amounts for children under ten or twelve years; but in every case attention should be paid to special circumstances—*e g.*, the amount of ventilation obtainable, the condition of the room, the class of people, the relationship of the persons overcrowded, etc.

There are other nuisances relating to the cleanliness, ventilation, and overcrowding of factories and workshops, and to smoke, which will be dealt with later on.

Section 92 requires the local authority to cause an inspection of its district to be made from time to time, to ascertain what nuisances exist calling for abatement, and to enforce the provisions of the Act, in order to abate the same; and Section 102 (see *ante*, p. 676) gives powers of entry to the officers of the local authority to carry out the provisions of the Act.

Public Health (London) Act, 1891.

The provisions relating to nuisances in London are the same as in the provinces. In order to prevent the possibility of nuisances being held to be only conditions which have actually caused injury to health, the words "or dangerous" have been introduced into this Act, so that the various sections read, "a nuisance, or injurious or dangerous to health." In London also (inhabited) premises without water fittings are a nuisance, and an occupied house without a proper and sufficient supply of water is a nuisance, which in the case of a dwelling-house renders it unfit for human habitation (section 48).

By section 100 it is provided that the County Council, when satisfied that a local sanitary authority has made default in doing its duty under the Act, with respect to the removal of any nuisance, the institution of any proceedings, or the enforcement of any by-law, may themselves do what is necessary to carry out the provisions of the Act, and recover the costs from the defaulting authority. On complaint by the County Council to the Local

Government Board that a sanitary authority is in default in executing or enforcing the provisions of the Act, the Board may, after inquiry, make an order limiting a time for the performance of the duty by the sanitary authority, enforceable by mandamus; or the Board may appoint the County Council to perform the duty, and in that event the Council is invested with all the powers of the sanitary authority, and can recover from the latter all expenses incurred, or can recoup themselves by levying the amount by a rate.

Public Health Act, 1875.

By section 299 of the Public Health Act, 1875, the Local Government Board has similar powers in respect of urban or rural authorities who have made default in enforcing any of the provisions of the Act which it is their duty to enforce. The County Council may make the complaint to the Board, and may be appointed by the Board to execute the provisions of the Act neglected by the local sanitary authority (Local Government Act, 1894).

Procedure to abate Nuisances, and to carry out the Provisions of the Acts.

Public Health Act, 1875.

Sections 94 to 100 deal with the procedure necessary. Information of a nuisance may be given by any aggrieved person, any two inhabitant householders, any officer of the local authority, the relieving officer, or police officer. A complaint having been made to a local authority of the existence of a nuisance, it is the duty of the sanitary inspector (inspector of nuisances) to visit the premises or place, and to report to the next meeting of his board (local authority). The latter, if satisfied of the existence of a nuisance, directs that a notice shall be served (Form A, Schedule IV.) on the person by whose act, default, or sufferance the nuisance arises or continues—or, if such person cannot be found, on the owner or occupier of the premises on which the nuisance arises – requiring him to abate the same within a specified time, and to execute the works necessary for that purpose. Where the nuisance arises from the want or defective construction of any structural convenience, or where there is no occupier of the premises, the notice must be served on the owner, but where the nuisance arises from the neglect or default of the occupier, the notice must be served on the *occupier*. Where the person causing the nuisance cannot be found, and it is clear that the nuisance does not arise or continue

by the act, default, or sufferance of the owner or occupier of the premises, the local authority may themselves abate the same.

"Owner" under this Act means the person for the time being receiving the rack-rent of the lands or premises in question, whether on his own account or as agent or trustee for any other person, or who would so receive the same if such lands or premises were let at a rack-rent, the latter term meaning rent which is not less than two-thirds of the full net annual value of the property out of which the rent arises.

Notices may be in print or writing, or partly in either, and are authenticated by the signature of the clerk, surveyor, or inspector of nuisances of the local authority. The notice may be served by delivering it or posting it to the residence of the person to whom it is addressed. The notice need not be addressed to any particular individual, but can be addressed to the owner or occupier of the premises, as the case may be, and either left upon the premises or, in the case of the premises being empty or there being no person on the premises to receive the notice, it may be fixed to some conspicuous part of the premises (sections 266, 267).

Should the notice or any of its requisitions not be complied with within the time specified, it is the duty of the inspector to report the matter to his board at its next meeting, who should instruct him to make a complaint before a justice (sworn information of the facts), who thereupon is to issue a summons (Form B, Schedule IV.) requiring the person on whom the notice was served to appear before a court of summary jurisdiction. The summons must be applied for within six months of the date of the original offence; otherwise all further proceedings are invalidated.

On the hearing of the summons, it will be necessary for the inspector to give evidence as to the existence of the nuisance, the dates of his visits to the premises, and the service of the notices in proper form. He must also be prepared to prove the ownership in case a particular person is summoned as owner, which is usually done by the production of the rent-book or the evidence of a tenant of the house. If the court is satisfied as to the existence of a nuisance, it may make (1) an *abatement order* (Form C)—an order to abate the nuisance within a specified time, and to do any works necessary for that purpose—or (2) a *prohibition order* (Form C), prohibiting the recurrence of the nuisance, with necessary works. The court may at the same time inflict a penalty not exceeding £5. Where the nuisance proved to exist is such as to render a house unfit for human habitation, the court may make (3) a *closing order*,

prohibiting the use of the house for human habitation until rendered fit for that purpose.

If the person on whom the magistrates' order is made fails to comply with its requirements within the time specified in the order, he can be again summoned; and if he fails to satisfy the court that he has used all due diligence to carry out such order, he may be fined 10s. per day during his default (abatement order), or 20s. per day (prohibition order). If the local authority prefers, it may direct its officers to enter the premises and execute the works specified in the order of the court, and recover in a summary manner the expenses so incurred from the person on whom the order is made (County Court proceedings).

A person convicted under these sections can appeal to the nex Court of Quarter Sessions, within fourteen days after the hearing, provided he gives notice of such intention to the local authority and enters into the necessary recognisance.

London.

The procedure in London is practically the same as that above detailed, with the exception that by section 3 of the London Act a sanitary inspector is required to send a "written intimation" of the existence of a nuisance, as soon as he becomes aware of it, to the person who may be required to abate it. In very many cases these written intimations lead to the abatement of the nuisance, without recourse having to be made to the service of statutory notices under the Act, authorized by resolution of the local authority. Furthermore, in the London Act "any person" may give information of a nuisance.

Both urban local authorities in the provinces and the Metropolitan local authorities are empowered to delegate to a committee their powers as to the reception and service of notices, the taking of legal proceedings, and generally the execution of the sanitary provisions of the Acts.

SMOKE NUISANCES.

Public Health Act, 1875.

Section 91 defines as a nuisance any fireplace or furnace used in any trade or manufacturing process which does not as far as practicable consume the smoke arising from the combustible used therein. There is, however, a proviso that, in the event of a person being summoned for this particular form of nuisance, the court must hold

that no nuisance has been created, and must dismiss the complaint, if it is satisfied that the furnace is constructed in such manner as to consume as far as practicable, having regard to the nature of the manufacture or trade, all smoke arising therefrom, and that such furnace has been carefully attended to by the person in charge.

The same section also defines as a nuisance any chimney (not being the chimney of a private dwelling-house) sending forth *black smoke* in such quantity as to be a nuisance.

In dealing with these smoke nuisances, the sanitary inspector, if so instructed by his authority, can at once make complaint to a justice and initiate proceedings. No notices are required to be served under the Act, though very often, as a matter of courtesy, information as to the cause of complaint is sent to the person responsible before an application is made to the court. If evidence is forthcoming that the smoke issuing was black and in such volume as to be a nuisance to the neighbourhood, in the absence of rebutting evidence, the magistrates are bound to convict. Should, however, the smoke not be black, but any lesser shade of colour (brown, yellow, etc.), evidence must be adduced by the prosecution either that the stoking is at fault, that coal of unsuitable quality is being used, or that the furnace is not constructed so as to consume as far as practicable the smoke arising from the combustible used therein. All these, naturally, are matters much more difficult of proof than where the only evidence necessary is the proof of black smoke and nuisance, and are also much more liable to be upset by rebutting evidence called on behalf of the defendant. The inspector should always make time observations, showing for each hour the numbers of minutes of black smoke, of coloured smoke, and of absence of visible smoke, respectively, and should produce this evidence in court.

London.

In London the smoke sections (23 and 24) of the Public Health (London) Act, 1891, contain practically identical provisions, the authorities being the various municipal boroughs.

Scavenging and Cleansing.

Public Health Act, 1875.

Section 42 provides that every local authority may, and when required by the Local Government Board shall, themselves undertake or contract for (1) the removal of house-refuse from premises, (2) the cleansing of earth-closets, privies, ashpits and cesspools,

(3) the cleansing and watering of the streets. If the local authority fails, without reasonable excuse, after written notice from the occupier of any house, to remove refuse or cleanse a privy, cesspool, etc., within seven days, the defaulting authority is liable to pay to the occupier 5s. per day during such default. When the local authority do not themselves undertake or contract for the removal of house-refuse and cleansing of privies, etc., they may make by-laws imposing these duties on the occupiers of premises, together with the cleansing of footways adjoining their premises.

Urban authorities may also make by-laws for the prevention of nuisances arising from snow, filth, dust, ashes, and rubbish, and for the prevention of the keeping of animals on premises so as to be injurious to health. In urban districts no swine may be kept in any dwelling-house so as to be a nuisance. The model by-laws of the Local Government Board require that swine must not be kept within 100 feet of any dwelling. An urban authority may also give notice by public announcement requiring the periodical removal of all manure or other refuse from mews and stables. Penalties are incurred for infringing these notices made by public announcement, without any further notice being required to be sent to the person in default.

Public Health Acts Amendment Act, 1890.

Under this Act sanitary authorities have power to cleanse alleys and courts, which are not highways, and to charge the occupiers of the houses abutting on the courts with the cost of doing so.

Public Health (London) Act, 1891.

In London footways as well as streets must be cleansed by the local authorities. If they fail to do so, they are liable to a fine of £20. The London authorities are also required to remove all house-refuse from premises. They are liable to a £20 fine if they neglect to do so for longer than forty-eight hours after the receipt of a complaint. Dustmen are prohibited from asking for gratuities. Local authorities may be required to remove trade refuse from any premises, but the occupier of the premises must pay a "reasonable" sum for the removal. Any question as to what constitutes trade-refuse is to be settled by a Petty Sessional Court (magistrate). Periodical removal of manure is required as under the 1875 Act.

The collection of house and street refuse is deemed an offensive trade in London, and the County Council has control over the local authorities in this matter as if the business was an offensive trade.

In London no swine may be kept on any premises within 40 yards of any street or public place.

Every sanitary authority is required to make by-laws (1) for the prevention of nuisances from snow, ashes, filth, etc., in any street; (2) for prevention of nuisance from offensive matter running out of trade premises; (3) for the keeping of animals on any premises; (4) for the paving of yards and open spaces in connection with dwelling-houses. Straw and tan may be laid in the streets to prevent noise in case of illness.

The County Council is required to make by-laws for prescribing the times—(1) for removing by road or water fæcal, offensive, or noxious matters or liquids, and the construction and covering of the vessels used for the purpose; (2) as to the removal and disposal of refuse, and the closing up of privies and cesspools.

These by-laws must be enforced by the local sanitary authorities.

Water-supply.

Public Health Act, 1875.

Power is given to all authorities, both urban and rural, to provide their districts with a supply of water proper and sufficient for public and private purposes (section 51). By section 62 a local authority may, on the report of their surveyor that any house within their district is without a proper supply of water, give written notice to the owner of the house requiring him within a specified time to obtain such supply, provided that it can be furnished at a cost not exceeding the water-rate authorized by any local Act in force within the district, or in the absence of any local Act at a cost not exceeding 2d. per week.

By section 70, on a representation being made to a local authority that within their district the water in any well, tank, or cistern, public or private, which is used, or likely to be used, by man for drinking or domestic purposes, or for manufacturing drinks for the use of man, is so polluted *as to be injurious to health*, the local authority may apply to a court of summary jurisdiction for a summons against the owner or occupier of the premises to which the well, tank, or cistern belongs. The court may at the hearing of the summons make an order for such well, tank, or cistern to be temporarily or permanently closed, or for the water to be used for certain purposes only. If the court sees fit, it may cause the water complained of to be analyzed at the cost of the local authority.

Public Health (Water) Act, 1878.

Section 3 makes it the duty of every *rural* sanitary authority to see that every occupied dwelling-house within their district has within a reasonable distance an available supply of wholesome water sufficient for the use of the inmates of the house. When, on the report of an officer of the rural authority, it appears that an occupied dwelling-house has not such a supply, and that it can be provided at a cost the interest of which at the rate of 5 per cent. would not exceed 2d. or 3d. per week, as the Local Government Board may determine, the authority may serve a notice on the owner to provide such a supply within a specified time. If such notice is not complied with, a second notice may be served, to the effect that after one month from the date of its service the authority will themselves provide such supply. At the expiration of the month, if the supply has not been provided, the authority may themselves execute the necessary works, and recover from the owner the expenses so incurred. By section 6 it is enacted that no newly-erected or rebuilt house in a rural district may be occupied unless the owner has obtained a certificate from the sanitary authority that there is provided within a reasonable distance of the house an available supply of wholesome water sufficient for the use of the house. Section 7 requires every rural sanitary authority to take such steps from time to time as may be necessary to ascertain the condition of the water-supply within their district; and section 11 authorizes the Local Government Board to invest by order any urban sanitary authority with all or any of the powers of this Act conferred upon rural authorities.

London.

In London the water is supplied by eight companies taking water from the Thames, New River, Lee, and deep wells in the chalk. Their powers and duties are regulated by their own (Companies Acts) and by the Metropolis Water Acts of 1852 and 1871. The Local Government Board has certain powers of control; for instance, it may make periodical examinations of the water, approve new sources of supply, approve the regulations made by the companies as regards pipes, taps, and other house fittings for the prevention of waste or contamination, and also hold inquiries into complaints made by consumers as to the quality or quantity of the water supplied for domestic use. The London County Council has power to require a constant supply of water in any district in

place of an intermittent supply. The company serves notices on the houses in the district to alter their pipes and fittings to meet the requirements prescribed for a constant service, and unless the company can show that more than 20 per cent. of the houses have not adopted the prescribed fittings, the supply must be made and continued constant. The County Council has power to supply the prescribed fittings on default of the owner or occupier of premises scheduled for a constant supply, and recover the costs so incurred.

By section 48 of the Public Health (London) Act, 1891, a newly-erected or rebuilt house must not be occupied until the sanitary authority has certified that it has a proper and sufficient supply of water. By section 49 any water company, on cutting off the water of an inhabited dwelling-house, is required to give within twenty-four hours written notice of the fact to the sanitary authority of the district under a £10 penalty. By section 50 every sanitary authority is required to make by-laws for securing the cleanliness and freedom from pollution of tanks, cisterns, and other receptacles used for storing water for drinking or domestic purposes, or for manufacturing drinks for the use of man. The other powers are similar to those in the Public Health Act, 1875, with the exception that in the case of wells, tanks, or cisterns, of which it is desired to obtain the closure, it is only necessary to prove that the water is "so polluted, or likely to be so polluted, as to be injurious or dangerous to health."

By the Water Companies (Regulation of Powers) Act, 1887, water companies are prohibited, under a £5 daily penalty, from cutting off the water-supply for non-payment of water rates in the case of houses for which the rates are compounded, and the water rate is payable by the landlord. In London the rateable value of such houses must be £20 or under, and in the provinces £10 or under.

Rivers Pollution.

By the Rivers Pollution Prevention Act, 1876, the following acts which might pollute a stream or interfere with its due flow are prohibited: (1) The discharge into any stream of solid refuse of any manufactory or quarry, or any rubbish, cinders, waste or putrid solid body; (2) the discharge of solid or liquid sewage matter, unless the best practicable and available means have been adopted to render harmless such matters; (3) the discharge of any poisonous, noxious, or polluting liquid from any manufactory, with the same

proviso; (4) the discharge of any solid or liquid matter from any mine, with the same proviso.

A sanitary authority can enforce the Act by taking legal proceedings, only with the consent of the Local Government Board. That Board, in giving or withholding consent, must have regard to the industrial interests involved, and to the circumstances and requirements of the locality.

If a sanitary authority declines to initiate proceedings, any aggrieved person may apply to the Local Government Board, who may direct the authority to proceed.

In this Act "stream" includes the sea to such extent, and tidal waters to such point, as may, after local inquiry and on sanitary grounds, be determined by the Local Government Board, by order published in the *London Gazette;* save, as aforesaid, it includes rivers, streams, canals, lakes, and water-courses, other than water-courses mainly used as sewers and emptying directly into the sea. "Solid matter" does not include particles of matter in suspension in water. "Polluting" does not include innocuous discoloration.

Owing to the great manufacturing interests involved, and the safeguards against procedure so abundantly introduced into the Act, it has been but little put into operation to prevent pollution of streams in the manufacturing counties.

Cellar Dwellings.

Public Health Act, 1875.

There is no definition of cellar or underground room in this Act, but in the Public Health (London) Act, 1891, an underground room includes any room of a house the surface of the floor of which room is more than 3 feet below the surface of the footway of the adjoining street, or of the ground adjoining or nearest to the room. Under the 1875 Act any cellar in which anyone passes the night is deemed to be occupied as a dwelling (section 74).

The Act prohibits the occupation of cellar-dwellings not lawfully occupied prior to the passing of the Act; and existing cellar-dwellings may only be occupied on certain conditions. No cellar may be occupied *separately* as a dwelling (*i.e.*, it may be occupied by a family in conjunction with other rooms on any other floor of the house, but not when used solely by one tenant or family) unless the following requisitions are complied with: (1) Unless the cellar is 7 feet in height from floor to ceiling throughout, 3 feet of this height being above the level of the street or

ground adjoining; (2) unless there is an open area outside and extending along the entire frontage of the cellar at least $2\frac{1}{2}$ feet wide and sunk 6 inches below the level of the floor of the cellar; (3) unless effectually drained by a drain which is nowhere less than 1 foot below the level of the floor of the cellar; (4) unless there is appurtenant to the cellar the use of a proper water-closet, earth-closet, or privy, and ashpit; (5) unless the cellar has a fireplace with chimney and flue, and an external window of at least 9 superficial feet in area clear of the sash-frame and made to open. In the case of a back-cellar occupied along with a front-cellar as part of the same letting, the window need not have a larger area than 4 superficial feet. Steps in the area giving access to the cellar are permitted, if not across or opposite to the window, and at least 6 inches away from the external wall. Similarly, steps are permitted to give access to the building above if not across or opposite to the window (section 72). There is a penalty of 20s. for every day a cellar is permitted to be occupied which does not comply with the above provisions, after notice from the sanitary authority; and in the case of two convictions within three months, an order may be made for the closing of the cellar.

Public Health (London) Act, 1891.

Under the London Act the ceiling of the cellar need be only 1 foot in height above the level of the ground or street adjoining when the open area is 6 feet or more in width. The open area must be properly paved and drained, and must be not less than 4 feet wide. The walls of the room must be constructed with a proper damp course and secured against dampness of soil, the soil immediately below the room being effectually drained. Any drain passing under the room is to be constructed of gas-tight pipe, and the room is to be secured against the rising of any effluvia or exhalation, and to be effectually ventilated. The window of the room is to have a total area clear of sash-frames equal to at least one-tenth of the floor area of the room, and is to be so constructed that one-half at least can be opened, the opening extending to the top of the window. In other respects the provisions are similar to the Act of 1875. Unless the sanitary authorities in London have specially dispensed with or modified any of the above requisites which involved, at the time of the Act coming into force, structural alterations of buildings (which they had power to do within six months of the commencement of the Act), the above provisions now apply to all underground rooms in London separately occupied as

dwellings. The modifications or dispensations might not in any case alter the requirements of the Metropolitan Management Acts which were in force prior to 1891.

Two or more underground rooms occupied together, and not in conjunction with other rooms above the basement, are deemed to be separately occupied as dwellings; and it is for the defendant to show that the underground room or rooms are not separately occupied. Evidence (such as the presence of a bed) giving rise to a probable presumption that some person passes the night there, is evidence, until the contrary is proved.

Common Lodging-houses.

Public Health Act, 1875.

There is no definition of common lodging-house in this Act, but it is usually held to mean a lodging-house in which persons of the poorer class are received for short periods (usually a night), and, although strangers to one another, are allowed to inhabit a common room (day-room or dormitory).

Every common lodging-house is required to be registered with the local authority, who must keep a register for the purpose, but may not register any such house until it has been inspected and approved for the purpose by one of its officers. A notice, with the words "Registered Common Lodging-house," is to be affixed to the outside of the house. Every local authority must make by-laws (1) as to the number of lodgers that may be received, and as to the separation of the sexes; (2) for promoting cleanliness and ventilation in such houses; (3) for the giving of notices and the taking precautions in the case of any infectious disease; and (4) generally for the well-ordering of such houses.

The model by-laws of the Local Government Board provide *inter alia* that the cubic space per head in the sleeping rooms is not to be less than 300 feet, two children counting as one adult; that no person above ten years of age must sleep in a room occupied by persons of the opposite sex, but rooms may be set apart for the sole use of married couples if every bed is screened off. No bed must be occupied by more than one male over ten years of age. The floors are to be swept daily, and washed once a week. Windows are to be opened fully for an hour in the morning, and the same in the afternoon. Beds must be stripped of clothes and exposed to the air for an hour each day, and must not be reoccupied within eight hours of being vacated. All refuse and slops must be removed

from the rooms before 10 a.m., and all utensils cleansed daily. The windows, yards, closets, and ashpits must be kept clean and in good order; and a sufficient supply of basins, towels, and water must be provided for the use of the lodgers. In the case of infectious disease occurring, the keeper of a common lodging-house must carry out all the measures and adopt all the precautions directed by the medical officer of health.

The Act requires all walls and ceilings to be limewashed twice a year (April and October), and the keeper may be required to make a daily report to the local authority as to the persons resorting to his house. He must give immediate notice of any illness or fever amongst his lodgers to the medical officer of health and to the poor-law relieving officer of the union or parish.

In London the common lodging-houses are regulated by the Common Lodging-houses Acts of 1851 and 1853, the provisions being practically identical with those above given. Until recently these houses were under the supervision of the Metropolitan Police; they are now, however, controlled by the London County Council.

Houses let in Lodgings.

Public Health Act, 1875 (*section* 90).

When required by order of the Local Government Board, local authorities are empowered to make by-laws for houses let in lodgings or occupied by members of more than one family. The by-laws thus made provide (1) for fixing the number of persons who may be taken in as lodgers, and for the separation of the sexes; (2) for the registration of the houses: (3) for their inspection; (4) for enforcing drainage and privy accommodation, and for promoting cleanliness and ventilation; (5) for the cleansing and limewashing of the premises, and for the paving of the courts and yards; (6) for the giving of notices and the taking of precautions in case of any infectious disease.

Houses in which the rooms are let at or above a certain weekly rental, to be determined by the local authority, are usually exempted from the operations of these by-laws.

The minimum cubic space permitted is usually 400 or 450 cubic feet per head in the case of a room used both as a dwelling and sleeping room, and 300 or 350 cubic feet in the case of a room used for sleeping purposes only. The other regulations that can be made are very similar to those enumerated as applicable in the case of common lodging-houses, with the exception that it is seldom that

any such by-laws attempt to enforce the separation of the sexes, and the limewashing need only be carried out once a year (April).

Public Health (London) Act, 1891 (*section* 94).

In London every sanitary authority (municipal borough) is required to make and enforce similar by-laws for houses in its district which are let in lodgings or occupied by members of more than one family. By-laws made under the Sanitary Act of 1866, prior to 1891, are not necessarily superseded by the by-laws to be made under the 1891 Act, unless the sanitary authority resolves that this should be done (section 142, 2, *b*).

INFECTIOUS DISEASES.

Infectious Disease (Notification) Act, 1889.

This Act, which was formerly permissive, is now made compulsory throughout the country.

The compulsorily notifiable infectious diseases are: Small-pox; cholera; diphtheria; membranous croup; erysipelas; scarlet fever or scarlatina; typhus; typhoid or enteric; relapsing, continued, and puerperal fevers. A local authority may by resolution make an order extending compulsory notification, either temporarily or permanently, to any other infectious disease not included in the above list, but the resolution must be confirmed by the Local Government Board. The diseases to which compulsory notification has been more commonly extended are diarrhœa, measles, whooping-cough, and chicken-pox. There has been some agitation in favour of including pulmonary tuberculosis amongst the notifiable diseases, but the Local Government Board has not so far sanctioned this novel departure.

The persons required to notify to the medical officer of health of the district are: (*a*) The head of the family to which the patient belongs; and in his default the nearest relative of the patient present in the building or in attendance on the patient; and in default of such relatives every person in charge of or in attendance on the patient; and in default of any such person the occupier of the building, shall, as soon as he becomes aware that the patient is suffering from an infectious disease to which this Act applies, send notice thereof to the medical officer of health of the district.

(*b*) Every medical practitioner attending on or called in to visit the patient shall forthwith, on becoming aware that the patient is suffering from an infectious disease to which this Act applies, send

to the medical officer of health for the district a certificate stating the name of the patient, the situation of the building, and the infectious disease from which in his opinion the patient is suffering. There is a 40s. penalty for failing to send the notice or certificate as required. No proceedings can be taken after a lapse of six months from the date of commission of the offence.

Although dual notification (by the householder and by the medical practitioner) is here provided for, notification by the householder is rarely, if ever, insisted on by sanitary authorities. The notification by the householder, or relatives, or person in charge, or occupier, is a safeguard for those cases in which medical assistance is not sought, but the practical difficulty of proving that any lay person was aware of the nature of an infectious disease occurring in his family or house is so great as to render the application of this section to concealed cases of infectious disease exceedingly difficult. Every medical man called in to see a case of infectious disease is bound to notify, even although this has already been done by another practitioner. In practice, however, this is but very seldom insisted on. Crown buildings are exempted from the operation of the Act.

Public Health Act, 1875.

Provisions against Infection.—Where any suitable hospital is provided within or near the district of a local authority, any person who is suffering from any dangerous infectious disorder, and is without proper lodging or accommodation, or lodged in a room occupied by more than one family, or is an inmate of any common lodging-house, or is on board any ship or vessel, may, on a certificate signed by any legally qualified medical practitioner, by order of any justice, be removed to such hospital at the cost of the local authority. This order may be addressed to a constable or to an officer of the local authority, and any person who wilfully disobeys or obstructs its execution is liable to a £10 penalty.

A suitable hospital would be an isolation or infectious disease hospital provided by the local authority, or established out of charitable funds, or the isolation wards of some general hospital or infirmary adapted for the treatment of infectious cases. The magistrate must be informed of the consent of the hospital authorities to receive the case.

There is no definition of "dangerous infectious disorder" in this Act, but it is usually held to denote any of the diseases which are compulsorily notifiable in the district. With regard to other

diseases, it lies in the discretion of the magistrate before whom a case is brought, to determine whether any particular infectious complaint is of a "dangerous" character, to prevent the spread of which precautions must be taken.

The words "without proper lodging or accommodation" are vague, but the most recent legal decision is that they have reference to the unfitness of the lodging or accommodation for the reception and treatment of a case of infectious illness, and to the possible danger to others from inadequate isolation of the case. The earlier decisions in effect ruled that the words had no such reference, and were only intended to apply to tramps and casuals sleeping out of doors or in places not intended for human habitation.

"Legally qualified medical practitioner" means a person registered under the Medical Act, 1858.

When it is intended to apply to a magistrate for an order for compulsory removal, notice of the time and place of making the application should be given to the patient or his friends.

The officers entrusted with the duty of carrying out the removal of the patient are not justified in employing force, either to enter the premises or apartment occupied by the patient, or to remove him if a strenuous resistance is offered. In such cases the only remedy is to summon the obstructing party with a view to the recovery of the £10 penalty. The magistrates' order for removal does not carry with it the power to detain the patient in hospital until he is recovered or no longer infectious.

Local authorities may provide ambulance carriages, for conveying infectious cases to hospital, and disinfecting-stations, and need not make any charge for the use of the ambulances or for disinfecting infected goods. They may also destroy infected articles and compensate the owners. They are also empowered to undertake the disinfection and cleansing of infected rooms or houses free of charge to the occupiers.

Any person who, while suffering from any dangerous infectious disorder, wilfully exposes himself without proper precautions against spreading the said disorder in any street, public place, shop, inn, or public conveyance, or enters any public conveyance without previously notifying to the driver that he is so suffering; and any person being in charge of any person so suffering who wilfully exposes such sufferer; and any person who gives, lends, sells, transmits, or exposes, without previous disinfection, any bedding, clothing, rags, or other things which have been exposed to infection, is liable to a penalty not exceeding £5.

The word "wilfully" is equivalent to knowingly. There can be no offence if there is no knowledge of the infectiousness of person or thing. The words "in charge" are indefinite, but they clearly apply to children, scholars in boarding-schools, and patients in public institutions, but they do not necessarily extend to domestic servants.

Every owner or driver of a public conveyance must immediately provide for the disinfection of such conveyance after it has to his knowledge conveyed any person suffering from a dangerous infectious disorder.

Penalties are also provided against any person (including innkeepers) who knowingly lets for hire any house or part of a house in which any person has been suffering from any dangerous infectious disorder, without having the same disinfected to the satisfaction of a medical practitioner. Any person, also, who lets a house or part of a house, and on being questioned by an intending tenant makes false statements as to the non-existence of infectious disease within six weeks previously, is liable to a penalty of £20 or a month's imprisonment.

Any local authority may establish a hospital for infectious diseases in its own district, and there is no restriction on the establishment of such a hospital in a neighbouring district; nor is it necessary to obtain the consent of the sanitary authority of the district in which it is proposed to establish a hospital.

Section 133 enables any local authority, with the sanction of the Local Government Board, to provide a temporary supply of medicine and medical assistance for the poorer inhabitants of their district. This section is intended to apply to times of epidemic, such as small-pox, cholera, plague, etc.

Infectious Disease (Prevention) Act, 1890.

This is a permissive Act. Any urban or rural sanitary authority may adopt the whole Act or one or more of its sections. The provisions of this Act, if adopted, shall apply to the infectious diseases specifically mentioned in the Infectious Diseases Notification Act, and may be applied to any other infectious disease in the same manner as that Act may be applied to such disease. That is to say, at the discretion of the sanitary authority it may be made obligatory on the public to take the same precautions to prevent the spread of measles, whooping-cough, or chicken-pox, as are necessary in the case of small-pox or typhus.

By section 15 of the Act, local authorities are required to provide, free of charge, temporary shelter or house accommodation, with any necessary attendants, for the members of any family in which infectious disease has appeared, who have been compelled to leave their homes to enable them to be disinfected.

Section 6 enables local authorities to compel the delivery by householders to them of infected goods for the purposes of disinfection, and provides for compensation to be paid by local authorities in the event of any damage to the goods.

Section 13 prohibits any person from knowingly casting into any dustbin or ashpit any infectious rubbish.

Section 7 prohibits under a £10 penalty the concealment of the existence of infectious disease by any lodger or tenant of a room, rooms, or house, who is giving up his tenancy, in cases where infectious disease has existed within a period of six weeks from the time of ceasing occupation. The concealment is of two kinds: (*a*) In not giving notice to the owner, and leaving the house or rooms without having them disinfected to the satisfaction of a medical practitioner; (*b*) in knowingly making false answers when questioned by the owner of the house, or by a person negotiating for the hire of the house or rooms. This section supplements sections 128 and 129 of the Public Health Act, 1875, which (see p. 696) heavily penalize owners or landlords for letting infected lodgings or making false statements when questioned as to the existence of infectious disease.

Section 12 provides for the detention in hospital, on the order of a magistrate, for a specified time, of any person who is a patient in an infectious disease hospital, and who would not on leaving such hospital be provided with accommodation, where proper precautions could be taken to prevent the spread of infection. Under the Public Health Act, 1875, only persons removed to hospital from ships can be detained in hospital, under regulations made by the sanitary authority.

Public Health (*London*) *Act*, 1891.

The infectious diseases sections of this Act incorporate the various sections of the Acts already mentioned as dealing with this subject. The London notification certificate differs from that required by the Infectious Disease (Notification) Act, 1889, in that the age and sex of the patient must be inserted, and also whether the case notified by the practitioner occurs in his private practice or in his practice as medical officer of any public body or institution. The fees are

the same under this Act as under the Notification Act—namely, 2s. 6d. for a private case notified, and 1s. for a public case.

Every municipal borough has power to extend compulsory notification to diseases other than those in the scheduled list (see p. 693) in its own district, whilst the London County Council has similar powers for the whole county of London. There is no power conferred on provincial County Councils to extend the Act to other diseases, as has been done for the London County Council.

In London the "dangerous infectious diseases" to which the provisions penalizing concealment and negligence refer, are those scheduled in the compulsorily notifiable list. In consequence of this, in London it is not compulsory to take any precautions with regard to the sufferers from measles, mumps, whooping-cough, or other non-notifiable disease. As in the Infectious Diseases (Prevention) Act, each sanitary authority has a discretionary power as to applying the penalizing sections to diseases ordinarily non-notifiable, but which have been rendered compulsorily notifiable by resolution. The provision of disinfecting-stations and goods removal vans by sanitary authorities is compulsory, and the disinfection is gratuitous, no costs or expenses incurred being recoverable by the sanitary authority. By section 70 no case of dangerous infectious disease may be conveyed in a cab, tram, omnibus, or other public conveyance. The use of all public conveyances for such purposes is absolutely prohibited in London. An ambulance carriage must be obtained from the Metropolitan Asylums Board, whenever it is desired to convey a person suffering from a notifiable infectious disease from one place to another, for which a charge of 5s. is made.

The fever hospitals of the Metropolis are under the control of the Metropolitan Asylums Board, and so is the removal of patients in ambulance carriages to or from the hospitals. The cases admitted to the Board's hospitals are small-pox, diphtheria, scarlet fever, enteric fever, and typhus. The Board is unable to acquire sites for the erection of hospitals unless with the consent of the Local Government Board.

Mortuaries, and Disposal of the Dead.

Public Health Act, 1875.

Any local authority may, and if required by the Local Government Board shall, provide a mortuary.

The body of any dead person may, by order of a justice, on the

production of a medical certificate, be removed to a mortuary, if it is in such a state as to endanger the health of the inmates of the house in which it is kept. The same power of removal applies to the body of a person dead of any infectious disease, if kept in a room where persons live or sleep.

Infectious Disease (Prevention) Act, 1890.

No infectious corpse is to be retained for more than forty-eight hours in a dwelling-place, sleeping-place, or workroom without the sanction of a medical practitioner. Section 9 gives power to prevent the removal of an infectious corpse from a hospital to the home of relations, or to any place except a mortuary. Section 10 enables a justice to order the removal of a dead body to a mortuary, and its immediate burial, if considered advisable, on the application of the medical officer of health; and section 11 provides for the case of removal of an infectious corpse in a public conveyance, which is unprovided for in the Act of 1875.

London.

The London Act contains almost identical provisions to the above, but the provisions for the most part relate to the bodies of persons who have died, not of "any infectious disease," but of a "dangerous infectious disease."

The Cleansing of Persons Act, 1897.

By this Act any local authority has the power of cleansing persons and their clothing from vermin, when an application is made to them; and local authorities may expend any reasonable sum on buildings, appliances, and attendants that may be required for the carrying out of the Act.

The Prevention of Epidemic Diseases.

Public Health Act, 1875.

Section 130 enables the Local Government Board to make regulations for the treatment of persons infected with cholera or other epidemic disease, and for preventing the spread of these diseases on land, and at sea up to the three-mile coast limit. By section 134, whenever any part of England appears to be threatened with or is affected by any formidable epidemic, endemic, or infectious disease, the Local Government Board may make regulations for (1) the speedy interment of the dead; (2) house-to-house visitation; (3) medical

aid and accommodation; (4) for the promotion of cleansing, ventilation, and disinfection, and for preventing the spread of disease. The local authority of any district within which such regulations are declared to be in force is charged with the execution and enforcement of the regulations. By the Public Health Act of 1889, regulations made by the Local Government Board in relation to cholera or choleraic diarrhœa may be put in force by officers of Customs, and may provide for the detention of vessels and of persons on board vessels.

The same provisions are in force in London.

Local Government Board Order, August 28, 1890: *Cholera Regulations.*

If there is cholera or choleraic diarrhœa on board a ship, or there are reasonable suspicions of such, any officer of Customs may cause the ship to be anchored where he directs, and detain her, no person being allowed to leave. Notice must then be given to the medical officer of health of the port, who is required to visit within twelve hours; otherwise the ship is released from detention. The medical officer, without notice, may himself inspect any vessel arriving from a port or place infected with cholera. If he finds the ship to be infected with cholera, he certifies accordingly, transmitting a copy of his certificate to the Local Government Board, and proceeds to examine every person on board the ship. In the case of persons infected, or suspected of being infected, the medical officer certifies to this effect, and directs their removal, if their condition admits of it, to the port isolation hospital, to be provided by the port sanitary authority. No person so certified may leave the hospital until free from the disease. A person suspected of being infected may be detained for two days on board the ship or in the hospital. Persons who are not infected are allowed to land immediately, after giving their names, destinations, and addresses to the medical officer, who is required to forward in each case these particulars to the clerk of the sanitary authority of the place where each person intends to go. The master of the ship is required to carry out all the medical officer's instructions as to preventing the spread of infection, by destruction of articles soiled with cholera discharges, disinfection of the ship, pumping out bilge-water, etc. The bodies of persons who have died of cholera are either to be taken out and buried at sea, or handed over to the sanitary authority for burial. Every cholera-infected ship is to hoist the yellow flag when within three miles of the coast.

By a further *order of August* 29, 1892, no person is allowed to land

from a cholera-infected ship, unless he satisfy the medical officer as to his name, place of destination, and future address; and the same applies to ships not infected with cholera, but which have passengers on board who are in a filthy or otherwise unwholesome condition, if the medical officer is of opinion that such a course is desirable to check the possible introduction or spread of cholera.

The Local Government Board has also published (August 26, 1892) a set of "Precautions against the Infection of Cholera" and a "General Memorandum on the Proceedings which are advisable in Places attacked or threatened by Epidemic Disease."

Housing of the Working Classes.

The principal Act dealing with the displacement of working-class populations from unhealthy areas and houses, and the rehousing of the displaced people, is the Housing of the Working Classes Act, 1890.

Unhealthy Areas.

Part I. of the Act is concerned with unhealthy areas. The authorities for this part of the Act are the urban sanitary authorities, and in London the London County Council and the Corporation for the City.

A medical officer of health is empowered to make an official representation to his authority—(*a*) that any houses, courts, or alleys are unfit for human habitation; (*b*) that the narrowness, closeness and bad arrangement, or the bad condition, of the streets and houses or groups of houses within such area, or the want of light, air, ventilation, and proper conveniences, or any other sanitary defects, or one or more of such causes, are dangerous or injurious to the health of the inhabitants, either of the buildings in the said area or of the neighbouring buildings; and that the evils connected with such houses, courts or alleys, and the sanitary defects in such area, cannot be effectually remedied otherwise than by an improvement scheme for the rearrangement and reconstruction of the streets and houses within such area.

The medical officer of health may make a representation on his own initiative, or he may be required to make it on the complaint of two or more justices of the peace of the district, or of twelve or more ratepayers. The local authority, on receiving the official representation, may pass a resolution to the effect that such area is an unhealthy area, and that an improvement scheme ought to be made in respect of it. After passing such resolution, they shall forthwith proceed to make a scheme,

The scheme may provide for the reconstruction and rearrangement of the streets and houses in the area, and generally for the opening out of the area, and the widening of approaches in order to improve the ventilation. The scheme must provide for proper sanitary arrangements, and for such dwelling accommodation for the working classes displaced as the Act directs. Due publicity must be given to the scheme, and notices must be served on all persons interested. Application is then made by the sanitary authority to the Local Government Board for a provisional order confirming the scheme. A local inquiry is then held by the Board, as to the correctness of the official representation and as to the sufficiency of the scheme. A provisional order may then be made by the Board authorizing the scheme, and this is subject to confirmation by Act of Parliament.

In London, representation may be made to the London County Council by any medical officer of health of a district, as well as by the county medical officer. The confirming body is the Home Secretary, not the Local Government Board, and accommodation must be provided in or near the scheduled area for the whole number of the working classes displaced. The Home Secretary, however, if satisfied that there is no necessity to rehouse all the working classes on the cleared area, may accept in substitution equally convenient accommodation not in or near the area, and may dispense with the obligation to rehouse to the extent of one-half the number displaced.

Both in the country and in London this part of the Act is practically unworkable. The cost is prohibitive, and the delays ensuing from the complexity of procedure often allow of a lapse of many years between the condemnation of the area and rebuilding on the cleared sites.

Unhealthy Dwelling-houses.

Part II. relates to individual unhealthy dwellings or to small groups of dwellings. The medical officer of health, on his own initiative, or on the requisition of four inhabitant householders, makes an official representation to his authority that a dwelling house or houses are in a state so dangerous or injurious to health as to be unfit for human habitation. The authority may then direct proceedings to be taken against the owner before a court of summary jurisdiction for the closure of the houses so represented. The court, on the hearing of the summons, may make a closing order for the houses, and may inflict a penalty upon the owner of £20.

The owner, under this Act, of leasehold premises, of which less than twenty-one years is unexpired, is not the lessee, but the ground landlord. Consequently the ground landlord by this Act is made responsible for the condition of premises over which he may have no control whatever.

Notice of the closing order is then served upon the occupying tenants of the houses, with notice to quit. Defaulting tenants who do not vacate the premises are liable to a penalty of 20s. a day during disobedience; but as such tenants have seldom any goods to distrain upon, and magistrates are reluctant to send them to prison, it is usually exceedingly difficult to get rid of the tenants, who continue to inhabit the premises until the houses are pulled down around them.

If nothing has been or is being done to render the closed dwelling-houses fit for human habitation, and it is represented to the authority that the continuance of the buildings is dangerous or injurious to the health of the public or of the inhabitants of neighbouring dwelling-houses, the authority must pass a resolution that it is expedient to order the demolition of the buildings. Notice of this must be served upon the owner, who is entitled to attend a meeting of the authority, to be held not less than one month after the service of the notice, for the further consideration of the resolution, when he may state his objections to the demolition. At this meeting an order must be made for the demolition of the buildings, unless the owner undertakes to execute forthwith the works necessary to render the houses fit for human habitation. If the houses have not been demolished within three months of the making of the order, the local authority may proceed to demolish them themselves.

Any person aggrieved by an order of the local authority under this part (II.) of this Act may appeal against the same to a Court of Quarter Sessions. Until this appeal has been heard or ceases to be prosecuted, the whole procedure under the Act has to stand still. This power of appeal by any aggrieved person practically makes the Act unworkable if opposition is encountered. The cost and the delays ensuing are prohibitive.

Under Part II. representation may be made as to "obstructive" buildings—that is to say, buildings which stop or interfere with the light and air about neighbouring buildings, or which prevent measures being carried into effect for remedying sanitary evils attaching to such buildings. The owner of the obstructive buildings is entitled to be heard by the local authority before an order is made for the demolition of the buildings. The site of the buildings

may either be purchased under compulsory powers or by agreement, and compensation is settled by arbitration.

Improvement or reconstruction schemes may be made under this part (II.) of the Act—(*a*) in respect of unhealthy dwelling-houses for which demolition orders have been made; (*b*) in the case of unhealthy areas which are too small to be dealt with under Part I. The improvement scheme may provide for the opening up of the area, the widening of streets and approaches, and the reconstruction and rearrangement of the buildings, with the erection of dwellings for the working classes.

The procedure is then very much the same as under Part I.—the application to the Local Government Board for a provisional order, the holding a local inquiry, and the making of a provisional order. This order requires no confirmation if the area is purchased by agreement. If the land is to be acquired by compulsory purchase, the order must be published and notice served upon the owners. If within two months after publication there is no petition by the owners, the order may be confirmed by the Board; but if there is a petition, the order is not valid until confirmed by Act of Parliament.

In London it has been customary for lengthy disputes to take place between the local district authorities and the London County Council as to whether schemes of improvement of unhealthy areas should be under Part I. or Part II. of the Act. In the former case the cost is borne by all ratepayers of London as a Metropolitan improvement, whilst in the latter the greater portion of the cost becomes a local debt. In the event of the representation relating to only ten houses, it must be made under Part II. In case of dispute the Home Secretary has power to appoint an arbitrator to decide as to whether the scheme is to be under Part I. or under Part II. In the latter event the County Council may be required to contribute to the expenses of the scheme. In consequence of these disputes, the great cost, and the complexity of procedure and resulting delays, the Act has been practically a failure.

Working-class Lodging-houses.

Part III. of the Act relates to the provision of working-class dwellings. This part of the Act is now entrusted to the new municipal boroughs in London. Prior to November, 1900, the London County Council was the authority. In other urban sanitary districts Part III. may be adopted with the sanction of the Local Government Board; in rural sanitary districts, it may be adopted

after inquiry by the County Council as to the necessity of providing working-class accommodation by parochial means.

Land may be acquired by a local authority either by agreement or by compulsory purchase, as provided by sections 175 to 178 of the Public Health Act, 1875. On this land, buildings suitable for lodging-houses for the working classes may be erected, fitted, and furnished. The local authority may purchase or lease lodging-houses already erected or to be built.

The general management, regulation, and control of the lodging-houses vests in the local authority, who may make by-laws for this purpose. Any tenant in receipt of poor-law relief is disqualified from remaining a tenant, except in case of accident or temporary illness.

The Housing Act also contains the following important provision: "In any contract for letting for habitation by persons of the working classes a house or part of a house, there shall be implied a condition that the house is at the commencement of the holding in all respects reasonably fit for human habitation." This section applies to houses let at a rental at which the rates may be compounded for—namely, £20 per annum in London, and £10 in the provinces.

By the Housing of the Working Classes Act, 1900, local authorities are now empowered to acquire land outside their own districts for the purpose of erecting lodging-houses for the working classes.

Offensive Trades.

The offensive trades enumerated in the Public Health Act, 1875 (section 112), are those of a blood-boiler, bone-boiler, fellmonger, soap-boiler, tallow-melter, and tripe-boiler. The model by-laws of the Local Government Board, in addition to the above, also relate to the trades of a leather-dresser, tanner, fat melter or extractor, glue-maker, size-maker, blood-drier, and gut-scraper. Section 112 prohibits any person from establishing anew within the district of an urban sanitary authority, without their consent in writing, any offensive trade. There is a £50 penalty, and a continuing penalty of 40s. a day. Urban authorities may make by-laws with regard to these trades.

On the certificate of their medical officer of health, or of two medical practitioners, or of any ten inhabitants of the district, that a trade process is causing effluvia which are a nuisance or injurious to health, magisterial proceedings must be taken by the urban sanitary authority against the defaulters for the recovery of penalties.

Similar proceedings may be taken in respect of a nuisance arising from an offensive trade, carried on outside the district, in a court having jurisdiction in the place where the offensive trade is situate.

The by-laws of the Local Government Board, which form the model for the by-laws that may be made by urban authorities, contain provisions for securing—(1) The storage of offensive materials in air-tight receptacles, so as to prevent escape of effluvia; (2) the passage of offensive vapours arising during processes of melting, boiling, etc., from the pans, either through the furnace or through condensers and thence through the furnace, so as to deprive them of all noxious properties; (3) the maintenance of efficient drainage on the premises, and the cooling of hot liquids before discharge into the drains; (4) the maintenance of the floors in good condition, and their daily cleansing, also the daily removal of all sweepings and refuse in covered receptacles; (5) the maintenance of walls in good order, their periodical scraping to remove any adherent filth, and their limewashing twice a year; (6) the cleansing of all utensils and vessels when not in use; (7) facilities for inspection by the sanitary authority's officers.

Under the Public Health (London) Act, 1891, the County Council is the authority for regulating offensive trades, making by-laws, and taking proceedings. The business of a soap-boiler may be carried on provided that no animal oils or fats, other than olein, are used in the manufacture. The fine for establishing anew in London the trade of blood-boiler, bone-boiler, manure manufacturer, soap-boiler, tallow-melter, or knacker, is £50, with a daily continuing penalty of £50. These businesses are absolutely prohibited from being started. With the consent of the London County Council, a fellmonger's, tripe-boiler's, or horse-slaughterer's business may be newly established.

Unsound Food.

Public Health Act, 1875 (*sections* 116-119).

Any medical officer of health or inspector of nuisances may at all reasonable times inspect any food exposed for sale, or deposited in any place for the purpose of sale, or of preparation for sale, and intended for the food of man, the proof that the same was not exposed or deposited for any such purpose, or was not intended for the food of man, resting with the party charged. If such food appears to be diseased, or unsound, or unwholesome, or unfit for the food of man, the officer may seize it, and convey it to a

magistrate, who, if satisfied, condemns the same, and orders it to be destroyed. The person from whom the seizure is made may then be proceeded against by summons to a court of summary jurisdiction, and is liable to a fine of £20 for every piece of food seized, or to imprisonment for three months. There is a £5 penalty for obstructing or impeding the sanitary authority's officer in the execution of his duty. In the event of permission being refused to enter any premises for the purpose of discovering if any unsound food is concealed therein, a complaint on oath must be made to a justice, who can grant a search-warrant. There is a penalty of £20 for obstructing an officer who is armed with a search-warrant.

Public Health (London) Act, 1891.

Similar provisions exist in London. In addition, proceedings may be taken against the vendor of unsound food to a private individual, if it can be shown that at the time of purchase the food was in such a condition as to be liable to be seized and condemned.

Horseflesh.

By the Sale of Horseflesh Regulation Act, 1889, which applies to the whole United Kingdom, the flesh of horses, asses, or mules must not be sold or kept for sale for human food except in a shop or stall, over which is an announcement, in legible characters 4 inches long, that horseflesh is sold there; nor may horseflesh be sold to any purchaser asking for other meat.

Canal Boats.

Under the Canal Boats Acts of 1877 and 1884, every canal boat used as a dwelling must be registered with the local authority as a dwelling for a certain number of persons of specified age and sex, by whom alone is it to be occupied. The registration authorities are one or more of the sanitary authorities abutting on the canal on which the canal boat plies, as may be prescribed by the Local Government Board. Every canal boat when registered must be lettered, marked as "registered," and numbered in a conspicuous manner, and must show the name of the place to which as registered she belongs. On the appearance of infectious disease on board a canal boat, the boat may be detained to be cleansed and disinfected after removal of the case to hospital.

The Local Government Board is empowered to make regulations for canal boats, which the local authorities are required to enforce.

These regulations provide that—There must be at least one dry and clean cabin. An after-cabin must contain not less than 180 cubic feet of free air space, and a fore-cabin 80 cubic feet. There must be ventilation and sleeping accommodation. One cabin must contain a stove and chimney. There must be storage for 3 gallons of water. If the boat carries foul cargoes, the hold must be separated from an inhabited cabin by a double bulkhead, with an interspace of 4 inches, the bulkhead next the cargo being water-tight; the space must be open throughout to the external air and provided with a pump for the removal of any liquid from such space. There must be 60 cubic feet of air space per head for persons over twelve years, and 40 cubic feet for children under twelve. No boy above fourteen or girl above twelve may sleep in a cabin occupied by a married couple; and males over fourteen and females over twelve must not sleep in the same cabin unless married. The interior of the cabin must be repainted every three years, and kept clean. Bilge-water must be pumped out daily. The master of the boat must notify the occurrence of infectious disease to the sanitary authority of the district he may be in; and if his boat is detained for disinfection, he may not proceed until he has obtained a medical certificate of cleansing and disinfection.

Movable Dwellings.

Under the Public Health Act, 1875 (section 314) local authorities are given power to make by-laws for securing the decent lodging and accommodation of hop-pickers within their district. By the Public Health (Fruit-pickers' Lodgings) Act, 1882, such by-laws may be made applicable to persons engaged in fruit and vegetable picking. The Local Government Board has framed model by-laws suitable for tents, sheds, barns, vans, and other places occupied as temporary dwellings. Under these by-laws the habitations must be clean, dry, weather-proof, lighted, and ventilated. Sixteen square feet of floor space must be allowed for each adult, and for every two children under ten years. There must be arrangements of screens for privacy where different sexes are accommodated. Cooking-places, adequate water-supply, and privy accommodation must be provided. There must be a sufficient supply of dry, clean straw, or other bedding. The premises must be kept in a cleanly condition at all times, and limewashed once a year.

Sections 9 and 10 of the Housing of the Working Classes Act, 1885, are not repealed, and give local authorities power to deal with movable or temporary dwellings in their districts as regards

nuisances, overcrowding, etc., with right of entry of officers, as if they were houses within the district.

Factories and Workshops.

Generally speaking, factories are places where mechanical power is used—that is to say, where engines are employed worked by steam, gas, water, or electricity. These are under the control of the Secretary of State for the Home Department, and are inspected by factory inspectors appointed by him.

Workshops are places where mechanical power is not used, and, so far as regards sanitation, are supervised by officers of the local sanitary authorities. There are, however, a large number of non-textile factories which are controlled by the Home Secretary whether mechanical power is employed in them or not. These are blast-furnaces, copper-mills, iron-mills, foundries, manufactories of earthenware, lucifer matches, percussion caps, cartridges, tobacco, paper, glass, print-works, fustian-cutting, printing, bookbinding, and flax scutch mills.

Public Health Act, 1875.

Section 91 defines as a nuisance any factory, workshop, or work-place—not already under the operation of any general Act (Factory and Workshops Acts, 1878, 1883, 1891, and 1895) for the regulation of factories or bakehouses—not kept in a cleanly state, or not ventilated in such a manner as to render harmless, as far as practicable, any gases, vapours, dust, or other impurities generated in the course of the work carried on therein that are a nuisance or injurious to health, or so overcrowded while work is carried on as to be dangerous or injurious to the health of those employed therein.

By section 38 local authorities may require in factories or workshops a sufficient number of water-closets, earth-closets, or privies and ashpits, for the separate use of each sex.

Private houses which are workplaces, and in which no mechanical power is used, and in which the workers are members of the same family inhabiting the house, are exempted.

Similar provisions are in force in the Metropolis.

Factory and Workshops Acts, 1878-1895.

By the Act of 1895 a factory or workshop is overcrowded if there is less than 250 cubic feet of space per head, and less than 400 cubic feet if overtime is being worked. If a factory inspector deems that there is any act or default in relation to the sanitary arrangements

of a factory or workshop remediable under the Public Health Act, he must give notice of the same to the sanitary authority of the district. It then becomes the duty of the sanitary authority to make such inquiry, and take such action within one month of the receipt of the notice, as may be necessary to enforce the law, and also to inform the factory inspector of the proceedings taken. In case of default of the sanitary authority, the factory inspector may himself take the necessary proceedings, and recover the expenses so incurred from the sanitary authority.

A medical officer of health or inspector of nuisances may certify that the cleansing of a workshop is necessary for the health of the workers, and the sanitary authority must then serve notice on the owner or occupier to carry out the necessary works. All manufacturers who employ outworkers are now required to keep lists of such outworkers, and to renew them when required. Such lists are to be open to inspection by the sanitary authority's officers whenever required. An outworker is one who takes work away from his place of employment, to carry out at his own home. No wearing apparel may be given to an outworker who resides in a building in which there is a case of small-pox or scarlet fever.

Steam laundries are factories; all other laundries are workshops, except such as are not carried on for purposes of gain, and such as employ only members of the same family.

In the case of every laundry worked by steam, water, or other mechanical power, a fan or other means of proper construction shall be provided and used for regulating the temperature in every ironing-room, and for carrying away the steam in every washhouse; all stoves for heating irons shall be sufficiently separated from any ironing-room; gas-irons emitting any noxious fumes shall not be used; and the floors shall be kept in a good condition, and drained in such a manner as will allow the water to flow off.

All the workrooms in factories and workshops must always be kept at a "reasonable temperature." The temperature is not defined in the 1895 Act, but it is generally held that it would be between 50° and 60° F.

A medical officer of health who becomes aware that any child under fourteen, young person between fourteen and eighteen, or woman over eighteen, is employed in a workshop or bakehouse must give written notice to the factory inspector.

Unhealthy Trades.

By the Factory Act of 1895 every medical practitioner attending on, or called in to visit, a patient whom he is of opinion is suffering from lead, phosphorus, or arsenical poisoning, or anthrax, contracted in any factory or workshop, must send to the Chief Inspector of Factories in London a notice stating the name, address of the patient, and disease from which he is suffering.

In every factory or workshop where lead, arsenic, or any other poisonous substance is used, suitable washing conveniences must be provided for the workers.

The following industries have been scheduled by the Home Secretary as dangerous to life or health: The manufacture of white lead, paints, and colours; the extraction of arsenic; the enamelling of iron plates; the manufacture of lucifer matches, except such as are made with red or amorphous phosphorus; the manufacture of earthenware, and of explosives in which di-nitro-benzole is used; chemical works; quarries; the making of red, orange, or yellow lead; lead-smelting; tinning or enamelling of iron hollow ware; electric accumulator works; flax-mills, and linen factories. With regard to all these trades special precautionary measures must be taken as regards cleanliness, ventilation, extraction of dust, etc.

In wearing-apparel factories the temperature must be kept at not less than 60° F. In textile factories, where the humidity of the air is increased by artificial means, the supply of air per head must be not less than 600 cubic feet per hour. The temperature must not be raised above 70° F., and wet and dry bulb thermometers must be suspended in the damping-rooms, from which readings are to be taken twice a day. The amount of permissible moisture is also regulated.

Bakehouses.

The officers of a sanitary authority have right of access to a retail bakehouse at any hour of the day or night. All walls and ceilings must be limewashed twice a year, or painted every seven years, and cleansed twice a year. No sleeping-room on the same floor may be occupied, unless completely separated from the bakehouse and provided with a window 9 square feet in area, half of which is made to open. No water-closet or privy is to be within the bakehouse, or to communicate directly with it. The cistern supplying water to a bakehouse must not supply a water-closet. No drain or drain inlet may be within the bakehouse. No underground bakehouse may be used unless so used prior to January 1, 1896.

Alkali, Chemical, and other Works.

Alkali works are those in which muriatic gas (HCl) is evolved. The other works which are subject to the Alkali, etc., Works Regulation Acts, 1881 and 1892, include sulphuric acid, chemical manure, gas liquor, nitric acid, ammonia, chlorine, arsenic, muriatic acid, nitrate and chloride of iron, tar, and zinc works; also the following, unless no H_2S is evolved, namely, alkali waste, barium, strontium, antimony sulphide, and bisulphide of carbon works.

All these works must be registered by the Local Government Board. In alkali works 95 per cent. of the HCl gas evolved must be condensed, and not more than $\frac{1}{5}$ grain of HCl gas per cubic foot of air, smoke, or chimney gases must escape from the works. Sulphurous acid and nitric gases must not be present in escaping air or smoke to a greater amount than the equivalent of 4 grains of SO_2 per cubic foot, at a temperature of 60° F., and at 30 inches barometric pressure. Acid drainage must not be allowed to mix with alkali waste so as to cause a nuisance, and means must be taken to prevent nuisance from alkali waste. Similar regulations apply to the sulphuric acid and other works enumerated above; and in all cases the best available means must be adopted to prevent the escape of noxious gases and to render them harmless and inoffensive.

Adulteration of Food and Drugs.

There are three Acts now in force relating to this subject, namely, the Sale of Food and Drugs Act, 1875; the Sale of Food and Drugs Act Amendment Act, 1879; and the Sale of Food and Drugs Act, 1899.

For the purposes of these Acts, the term "food" includes every article used for food or drink by man, other than drugs or water, and any article which ordinarily enters into or is used in the composition or preparation of human food, and also includes flavouring matters and condiments. The term "drug" includes medicines for internal or external use.

These Acts prohibit: (1) The mixing, colouring, staining, or powdering any article of food with any ingredient or material so as to render the article injurious to health, with the intent that the same may be sold in that state; and no article so mixed may be sold; penalty for contravention, £50 (section 3, 1875 Act). (2) The mixing, colouring, staining, or powdering any drug with any ingredient or material so as to affect injuriously the quality or potency

of such drug; and no drug so mixed may be sold; penalty, £50: provided that no person shall be liable to be convicted if he proves that he was unaware at the time of sale of the food or drug that these were so mixed or coloured (section 4, 1875 Act). (3) The sale, to the prejudice of the purchaser, of any article of food or any drug which is not of the nature, substance, and quality of the article demanded by such purchaser; penalty, £20. Where any matter has been added to the food or drug, there is no offence if the same has not been fraudulently used, but is required for preparing the food or drug as an article of commerce; neither does this section apply to proprietary or patented medicines or foods (section 6, 1875 Act). Under this section a great majority of the prosecutions for adulteration are instituted. By the 1879 Act it is provided that it shall be no defence to a prosecution that the purchaser, having bought only for analysis, was not prejudiced by the sale; neither is it a valid defence to prove that the food or drug purchased, though defective in nature, or in substance, or in quality, was not defective in all three respects.

Section 7 of the 1875 Act prohibits the sale of any compound, article of food, or compounded drug which is not composed of ingredients in accordance with the demand of the purchaser; penalty, £20. By this section, the making up of medicines in accordance with prescription can be insisted upon; and the section is chiefly of value for that purpose. With regard to the sale of drugs and medicines, these articles must be in accordance with the requirements of the last published edition of the British Pharmacopœia, both as regards the presence of particular ingredients, their relative proportions, and their strengths.

By section 8 of the 1875 Act, in the sale of articles of food or drugs which are mixed with other ingredients which are not injurious to health and not fraudulently added, there is no offence if the article sold has a label on it distinctly and legibly written or printed to the effect that the same is "mixed." This label must not be obscured by other matter on it (section 12, 1899 Act).

By section 9 of the 1875 Act, no person shall, with the intent that the same may be sold in its altered state, without notice, abstract from an article of food any part of it so as to affect injuriously its quality, substance, or nature; and no person shall sell any article so altered without making disclosure of the alteration; penalty, £20. This section is invoked in cases of prosecution for selling skimmed or separated milk.

The 1875 Act provides for the appointment of public analysts by

local authorities, and for the analysis of articles of food and drugs submitted to them by private purchasers, on payment of a fee of 10s. 6d., as well as by inspectors appointed under the Act to purchase samples for analysis. The form of certificate to be given by the public analyst is set out in the schedule to the Act. In this certificate, in the case of adulterated articles containing foreign ingredients, the public analyst is required to state the parts or percentages of foreign ingredients in relation to the bulk or total weight of the article; and in the case of foods liable to decompose, he must certify that no change had taken place in the constitution of the article that would interfere with the analysis.

By section 14 of the 1875 Act and section 13 of the 1899 Act, the person purchasing for analysis must, after the purchase has been completed, forthwith notify to the seller his intention to have the same analyzed by the public analyst, and must divide the article into three parts, to be then and there separated, and each part to be marked, sealed, or fastened up as its nature will permit, and shall, if required to do so, deliver one of the parts to the seller. One of the parts is to be retained for future comparison, and produced in court in the event of a prosecution. The third part is to be taken to the public analyst, or sent to him by registered parcel post.

If the offer to divide is refused, the analyst must divide the sample into two parts, and remit one part to the purchaser for production in case proceedings shall afterwards be taken.

Any person refusing to sell to an inspector or officer is liable to a £10 penalty.

All proceedings under these Acts must be instituted within twenty-eight days of the date of purchase. The summons must state the particulars of the offence alleged, must not be made returnable in less time than fourteen days from the day on which it is served upon the defendant, and must be served with a copy of the certificate of the public analyst obtained on behalf of the prosecutor (section 19, 1899 Act). At the hearing of the summons, the certificate of the public analyst is sufficient evidence for the prosecution, unless the defendant requires him to be called (section 21, 1875 Act); and on behalf of the defendant a public analyst's certificate is sufficient evidence, if a copy has been sent to the prosecutor three clear days before the summons is heard. The justices *may* order the sample produced in court by the prosecutor to be sent to the Commissioners of Inland Revenue to be analyzed by the chemical officers at Somerset House, and may adjourn the hearing

to obtain the Somerset House certificate (section 22, 1875 Act). They *must* do so at the request of either party, by section 21 of the 1899 Act.

By section 25 of the 1875 Act, if the defendant prove that he had purchased the article as the same in nature, substance, and quality as that demanded by the prosecutor, and with a written warranty to that effect, that he had no reason to disbelieve the warranty, and that he sold the article in the same state as when he purchased it, he is not guilty. By section 20 of the 1899 Act the warranty defence is not available, unless a copy of it has been sent to the prosecutor within seven days after the service of the summons, with the statement that the warranty will be relied on, and specifying the name and address of the person from whom the warranty or invoice was received. This person must also be informed of the defendant's intention to rely on the warranty, and he is entitled to give evidence at the hearing. Any person giving a false warranty is liable to heavy penalties, unless he prove that when he gave the warranty he had reason to believe that it was true.

MILK.—By section 3 of the 1879 Act, an inspector may take a sample of milk for analysis which is consigned from one person to another in pursuance of any contract. The sample must be taken at the place of delivery, which in towns is usually a railway-station, where the milk passes into the hands of the consignee or his servants.

By section 14 of the Sale of Food and Drugs Act, 1899, any other article of food may be sampled in course of delivery at the request or with the consent of the consignee.

By section 4 of the 1899 Act the Board of Agriculture can frame standards for the composition of genuine milk, including condensed milk, cream, butter, and cheese, departures from which standard raise a presumption, until the contrary is proved, that the article is adulterated. Analysts must have regard to these standards. Any person selling milk or cream in any street or public place must have conspicuously inscribed on his vehicle or can or churn his name and address (section 9). Every tin of condensed "separated" or "skimmed" milk must bear a label clearly visible to the purchaser—"Machine-skimmed Milk" or "Skimmed Milk"—in large and legible type. No tin unless so labelled may be sold or exposed or offered for sale.

BUTTER AND MARGARINE.—By the Margarine Act, 1887, butter is defined as made exclusively from milk or cream, or both, with or without salt or other preservative, and with or without added

colouring matter. Margarine includes all substances, whether compounds or otherwise, prepared in imitation of butter, and whether mixed with butter or not. Every package of margarine must be so marked in printed capital letters not less than ¾ inch square; if exposed for sale by retail, the label must be printed "Margarine" in letters 1½ inches square. When margarine is sold retail, it must be delivered to the purchaser in a paper wrapper on which "Margarine" is printed in capital block letters not less than ½ inch long and distinctly legible, and no other printed matter must appear on the wrapper (Sale of Food and Drugs Act, 1899, section 6). An officer taking samples under this Act is not required to go through the form of purchase, but otherwise the procedure is the same as under the Sale of Food and Drugs Acts. Any substance not marked as margarine is presumed to be exposed for sale as butter. By the Sale of Food and Drugs Act, 1899, "Margarine" and "Margarine-cheese" must be branded on the package itself, and not solely on an attached label or ticket, in capital block letters ½ inch long. By this Act also margarine-cheese is included in all provisions relating to margarine, and the same measures must be taken to differentiate margarine-cheese and cheese as are necessary to differentiate margarine and butter. Manufactories of margarine and of margarine-cheese must be registered with the local authorities of the district in which they are situate, and notice of registration must be sent to the Board of Agriculture. No margarine imported, manufactured, or sold may contain more than 10 per cent. of butter-fat (Sale of Food and Drugs Act, 1899, section 8).

Spirits.—By section 6 of the Sale of Food and Drugs Act Amendment Act, 1879, brandy, whisky, and rum may be sold 25 degrees under proof and gin 35 degrees under proof. Spirits may be sold diluted to a greater extent if a customer's attention is called to the fact of greater dilution being practised in the establishment in which he is being served, but not otherwise.

The chief provisions of the Sale of Food and Drugs Act, 1899, have been alluded to above. In addition, it may be noted that importers of margarine, margarine-cheese, skimmed or separated condensed milk, and of other adulterated or impoverished articles of food, unless such articles are conspicuously labelled or described, are liable to a penalty. The Local Government Board and the Board of Agriculture may direct their officers to procure for analysis any article of food in any district. Such officer divides his sample into four parts, sending one part to his Board and one to the public

analyst of the district, whose fee is payable by the local authority of the district. If the sample is adulterated, the analyst's certificate is to be sent to the local authority, who are required to prosecute. By this Act also every local authority is now required to appoint a public analyst and to administer the Acts. In case of failure to do so, either the Local Government Board or the Board of Agriculture may empower an officer to execute and enforce the provisions of the Acts, and the expenses so incurred must be paid by the local authority to the Board on demand. Public analysts to be appointed must furnish such proof of competency as the regulations of the Local Government Board may require.

Slaughter-houses.

By section 4 of the Public Health Act, 1875, a slaughter-house includes knackers' yards and any building or place used for slaughtering cattle, horses, or other animals for sale.

By section 169 of the same Act, an urban authority may provide (public) slaughter-houses, sometimes called municipal abattoirs, and must make by-laws for the management and charges for the use of them. They may also license existing slaughter-houses, and without their license no place may be used for the purpose which was not so used prior to 1875. This license does not require periodical renewal when once given. With regard to slaughter-houses in use prior to the Act, they need not be licensed, but they must be registered with the local authority. The owner or occupier of a licensed or registered slaughter-house is required to affix a notice to that effect on some conspicuous part of the premises.

In places where Part III. of the Public Health Acts Amendment Act, 1890, has been adopted, licenses for slaughter-houses may be limited to twelve months, and may be revoked if the occupier has been convicted of selling unsound meat or exposing it for sale. This Act does not apply, so far as regards licenses for limited periods, to slaughter-houses already licensed or registered before the adoption of the Act.

The Local Government Board has suggested the following rules as to site and structure, which should be complied with by slaughter-houses seeking a license: (1) The premises should not be within 100 feet of any dwelling-house, and should be freely exposed to the air on two sides at least. (2) Lairs for cattle should not be within 100 feet of a dwelling-house. (3) The slaughter-house should not be below the ground-level. (4) The approach should not be on an incline of more than one in four, nor pass through any

dwelling-house or shop. (5) There should be no room or loft over the slaughter-house. (6) The water-tank must be of adequate size, with its bottom not less than 6 feet above the floor of the slaughter-house. (7) There should be thorough ventilation of the slaughter-house. (8) The floor should be well paved with asphalt or concrete, laid with proper slope and channel to a gulley, with trap and grating, the bars of which should not be more than $\frac{3}{8}$ inch apart. There must be effectual drainage. (9) The surface of the walls in the interior should be covered with hard, smooth, impervious material to a sufficient height. (10) There must be no water-closet, privy, or cesspool within the slaughter-house. (11) There must be no direct communication between the slaughter-house and any stable, water-closet, privy, or cesspool. (12) Every lair for beasts must be properly paved, drained, and ventilated. No habitable room is to be constructed over any lair.

The Local Government Board has also issued model by-laws as to—(1) Applications for licenses for existing premises or for erection of new premises. (2) Registration of premises. (3) Access for inspection by sanitary officers. (4) Water to be supplied to every animal in a lair. (5) Mode of slaughter: cattle to be secured by the head before felling. (6) Drainage, water-supply, and ventilation. (7) Cleanliness of premises: walls and floor to be kept in repair, and cleansed within three hours after slaughtering; walls and ceiling to be limewashed four times yearly. (8) No dogs to be kept in a slaughter-house; and no other animal, unless intended for slaughtering, and then only in a lair, and not longer than necessary to prepare it for killing by fasting. (9) All refuse, blood, manure, and garbage to be placed in suitable vessels of non-absorbent material with close-fitting covers, immediately after slaughtering, which are to be removed within twenty-four hours, the vessels being then cleansed. All skins, fat, and offal to be removed within twenty-four hours.

Any person guilty of an infringement of the by-laws, when in force in a district, is liable to have his license suspended for two months, on conviction before justices, or revoked in the case of a second offence.

In London all slaughter-houses are annually licensed by the London County Council.

Dairies, Cowsheds, and Milkshops.

Under the Contagious Diseases (Animals) Acts, 1878-1886, the Local Government Board has issued the Dairies, Cowsheds, and

Milkshops Orders of 1885, 1886, and 1899. The main provisions of these orders are as follows: (1) Every cowkeeper, dairyman, and purveyor of milk must be registered in a register to be kept by the sanitary authority of the district. Cowkeepers and dairymen who only make or sell butter and cheese, and persons who sell milk from their own cows in small quantities to workmen or neighbours, need not be registered. (2) No new dairy or cowshed may be occupied until provision is made to the reasonable satisfaction of the sanitary authority for the lighting, ventilation, air space, cleansing, drainage, and water-supply of the premises. (3) As regards existing dairies and cowsheds, these matters must be attended to as far as is necessary or proper for the health and good condition of the cattle, the cleanliness of the milk-vessels, and for the protection of milk against infection. (4) No cowkeeper or dairyman suffering from a dangerous infectious disorder, or having been recently in contact with a person so suffering, may milk cows, handle milk-vessels, or assist in the trade so far as regards the production, distribution, or storage of milk, nor may he allow any person so suffering to do so. (5) After a month's notice from the local authority, no water-closet, privy, cesspool, or urinal is allowed to be within, or communicate directly with, or ventilate into any dairy, milk-store, or milkshop. (6) No milk-store or milkshop is to be used as a sleeping apartment, or for any other purpose likely to cause contamination of the milk. No swine may be kept in cowsheds or milk-stores. (7) The milk of a cow suffering from cattle-plague, pleuro-pneumonia, foot and mouth disease, or tubercular deposits in the udder (when so certified by a veterinary surgeon), shall not be mixed with other milk, shall not be sold or used as human food, and shall not be sold or used for food of animals, unless it has been boiled.

The above order of the Local Government Board also confers power upon any urban or rural sanitary authority to make and enforce regulations for the inspection of cattle in dairies and cowsheds; for prescribing and regulating their lighting, ventilation, cleansing, drainage, and water-supply; for securing the cleanliness of milkshops, milk-stores, and milk-vessels; and for prescribing precautions to be taken by all purveyors of milk against infection or contamination.

Each cow is usually required to have a space of 8 feet by 4 feet in a separate stall, and two cows 8 feet by 7 feet in a common stall. The minimum air space is usually fixed at 600 cubic feet, but when the ventilation is imperfect, 800 cubic feet are required per head.

The floors must be imperviously paved and drained to gullies situated outside of the shed; the lower parts of walls to be of non-absorbent material; there must be no communication of the cow-shed with a water-closet or privy; and 12 gallons of water must be provided for the use of each cow. All milk-vessels to be steamed or scalded immediately after use.

In those districts which have adopted the Infectious Disease Prevention Act, 1890, the medical officer of health, if of opinion that the consumption of milk from any dairy situate within or without his district is likely to cause infectious disease in his district, may, by order of a justice of the place in which the dairy is situate, inspect such dairy, and, if accompanied by a veterinary inspector, inspect the animals therein. If satisfied that the milk sent out from the dairy is likely to cause infection, the medical officer reports to his authority, who may give notice to the dairyman to appear before them, after twenty-four hours' notice, and make an order on him not to supply any more milk within the district.

In London the Public Health (London) Act, 1891, confers similar powers upon the medical officer of health. In London cowhouses have to obtain an annual license from the County Council, and all purveyors of milk have to be registered with the Council. All cow-sheds and dairies are subject to the Council's by-laws, and notice of the occurrence of any case of infectious disease on the premises has to be sent to the Council.

Cemeteries and Burial-grounds.

By the Public Health (Interments) Act, 1879, both urban and rural authorities may provide cemeteries for their districts, and must do so if required by the Local Government Board on the ground of inadequacy of existing burial-places, or of their being a danger to the public health.

An existing burial-ground may be closed by the Home Secretary by Order in Council under the provisions of the Burial Act, 1853. Interments within the walls of churches built after 1848 are forbidden by the Public Health Act, 1875.

The Regulations for Burial-grounds issued by the Home Secretary in 1863 provide *inter alia*—(1) For the fencing and underdraining of the site, to prevent water rising into any grave; (2) grave spaces to be laid out, and a corresponding plan kept, such spaces to be 9 feet by 4 feet for adults, and 4½ feet by 4 feet for children under twelve years; (3) a register of graves is to be kept; (4) a body

buried in a walled vault is to be cemented in, and never afterwards disturbed; (5) only one body to be buried in a grave at one time, unless members of the same family; (6) no grave to be reopened until fourteen years have elapsed for an adult, or eight years for a child, unless to bury another member of the same family, in which case at least 1 foot of earth is to be left undisturbed over the previously buried coffin; (7) no adult body to be buried within less than 4 feet of the level of the ground; a child under twelve may be buried within 3 feet.

By section 141 of the Public Health Act, 1875, local authorities may make by-laws for the management of cemeteries.

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